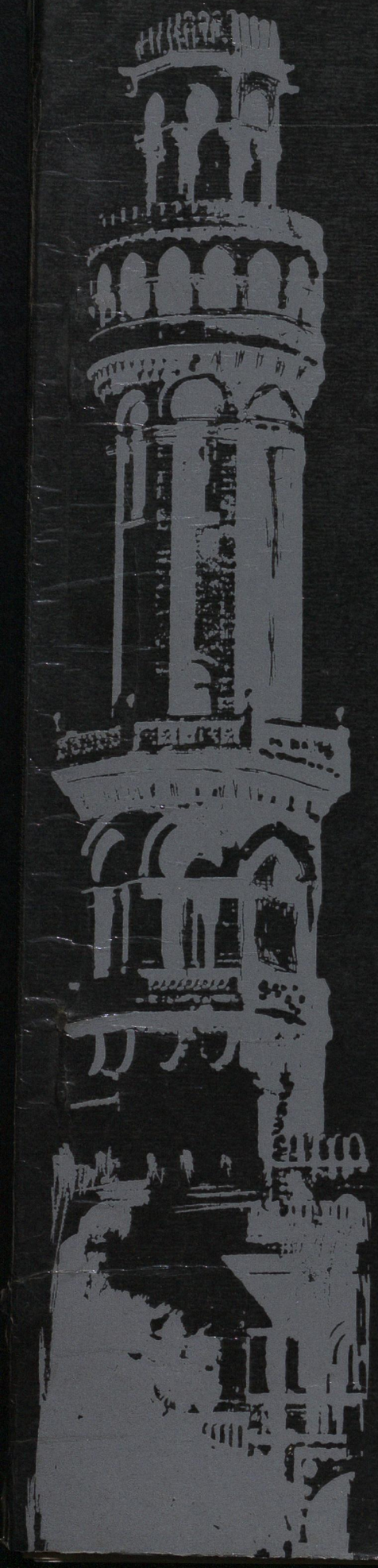


K. S. KRISHNAN

BIRTH CENTENARY

SOUVENIR



PLATINUM JUBILEE YEAR 1998

DEPARTMENT OF PHYSICS

UNIVERSITY OF ALLAHABAD

K. S. KRISHNAN

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(1898 - 1998)

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Prof. K. S. Krishnan, F.R.S.

Head of Physics Department (1942 - 47)

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PREFACE

The Physics Department has the proud privilege of being guided and headed by stalwarts like Prof. M. N. Saha and Prof. K. S. Krishnan. Both of them were honoured with the Fellowship of Royal Society (FRS) and Indian National Science Academy (FNA). The department has produced many international and national fame professors in many areas including Indian Institutes of Technology, Indian and Foreign Universities and Directors of National Laboratories, Scientific Advisors to the Ministry of Defence, Governors, ministers and administrators and social workers.

Remarkably, most of the Directors of the prestigious National Physical Laboratory in Delhi are from this department. The first Director, Prof. K. S. Krishnan, left Allahabad University in 1947. This was followed by Dr. P. K. Kichlu, Prof. A. R. Verma and Prof. S. K. Joshi.

To preserve the memory of an illustrious person, like Prof. K. S. Krishnan, and to highlight the glorious past of the department and its future course of actions, the Physics Department of the Allahabad University decided to organise a yearlong programme to celebrate the Platinum Jubilee and the Birth Centenary of Prof. K. S. Krishnan.

The year long activities have been lectures on the frontiers of physics by eminent physicists from all parts of the country. To name a few, we had Prof. M. Lakshmanan, F.N.A. from Trichinapply, Prof. S. K. Joshi, F.N.A., Prof. Ashok Sen, F.R.S., Prof. O. N. Srivastava, F.N.A., BHU, Prof. G. P. Srivastava, UK, Dr. R. N. Bhargava, USA, Prof. K. P. Sinha, F.N.A. Bangalore.

Prof. K. S. Krishnan's main interest shifted to Condensed Matter Physics in later years. While at Allahabad, Prof. Krishnan with Prof. A. B. Bhatia worked on the theory of resistivity of metals and alloys. It was considered befitting to organise a National Conference on "Condensed Matter Physics". The department is at present very much involved in the theoretical study of a wide variety of materials, both pure and with all types of defects and also the experimental study of new materials. Recently, a new specialised course of solid state physics has been started for M.Sc. (Final) students. The course comprises both the theory papers and the laboratory training. Another new specialised course for M.Sc. (Final) students on Quantum Optics will start soon.

The Physics Department has the privilege of acquiring very fast parallel processing HP computer configurations, first of its kind in the Indian Universities for investigations of different types of quite complex solids containing all kinds of defects. Facilities for measuring electrical properties of all types of materials ranging from DC to 26.5 Ghz have been developed. Thermodynamics of phase transitions can also be investigated.

In the organisation of the Conference, efforts have been made to invite discussions on almost all the frontiers of condensed matter physics like high Tc-superconductors, 1998 Nobel prize winning fractional quantum Hall effect, quantum confined structures like nano crystals and quantum wells, liquid crystals, non-linear and quantum optics, criticalities, semiconducting and ferroelectric crystals and films, amorphous silicon, materials at high pressure and magnetism.

The organising committee expresses its immense happiness in welcoming all the participants of the conference and is of firm view that the deliberations of the conference would be of high level and fruitful to the attending scientific community. I hope that the conference would be instrumental in infusing new life in the research and teaching activities of not only of the Physics Department but also in the sister departments of the Science faculty of University of Allahabad.

Chairman *B. K. AGRAWAL*
National Conference on
Condensed Matter Physics

PROF. K. S. KRISHNAN BIRTH CENTENARY

CONFERENCE ON CONDENSED MATTER PHYSICS

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SECTION 1

K. S. KRISHNAN

SCIENTIST WITH A VISION

He is a great scientist, but something much more. He is a perfect citizen, a whole man with an integrated personality.

- Jawaharlal Nehru
on Krishnan's sixtieth birthday

- *Professor K. S. Krishnan, F.R.S.*
- *Sir K. S. Krishnan and the International Geophysical Year*
- *K. S. Krishnan*
- *Research Papers of Professor K. S. Krishnan*
- *Prof. K. S. Krishnan, F.R.S. – A Profile*
- *Presidential address to the Physics Section of Indian Science Congress by Professor K. S. Krishnan*

Professor K. S. Krishnan, F.R.S.[1]

K. R. Ramanathan

Professor K. S. Krishnan, distinguished physicist, philosopher and Acharya, will be sixty years old on 3 December 1958. On that auspicious occasion, we wish to convey to him our cordial felicitations and good wishes for his continued good health, activity and service to science, philosophy and international goodwill for many, many years to come.

Creative thinkers like Krishnan with understanding, critical judgement and tolerance, men who have a mind of their own and carry out their inner dharma unperturbed by changing fashions men who "explore the explorable and quietly venerate the inexplorable" are not to be found in large numbers in any country. When we do find such persons, we do well to honour them.

Kariamanikkam Srinivasa Krishnan was born in the village of Watrap near Srivilliputtur in the Tirunelveli (now Ramnad) district in Tamilnad. His father was a scholar of the old school deeply versed in Tamil and Sanskrit religious literature. He spent a good part of his time in pilgrimages to South Indian temples, particularly to Srirangam and Tirupathi. Krishnan had his early schooling in Watrap and Srivilliputtur and was brought up in a rural atmosphere. After matriculation, he had his collegiate education first in the American College, Madura, and later in the Christian College, Madras. After graduating in physics from the Christian College, he was for a few years a Demonstrator in Chemistry in the same college. He took his teaching seriously and was a very popular teacher. I have heard that he used to conduct informal lunch-hour discussion classes which were attended by large number of students from all the neighbouring colleges and in which any questions in mathematics, physics or chemistry could be raised and would be answered there and then, starting from first principles.

Being of an inquiring turn of mind and anxious to qualify himself for a life of scientific study and research, Krishnan went to Calcutta to study physics under Professor C. V. Raman. He joined the University College, Calcutta, for his M.Sc. Professor Raman's lectures which have a range, penetration and fascination, all their own, influenced Krishnan greatly and he absorbed from Raman a deep and abiding interest in optics and molecular physics. For some reason, Krishnan did not take the M.Sc. examination, but Professor Raman accepted him as a research student in the Indian Association for the Cultivation of Science, 210 Bowbazar Street. This was in 1923. Krishnan continued to work there as a research scholar till December 1928, when he left for Dacca as a Reader in Physics in the university there.

The period of Krishnan's stay in the Indian Association for the Cultivation of Science was a period of exceptional activity. The new subject of molecular scattering of light and of X-rays was being rapidly developed by Professor Raman and there were a number of bright young men

1. This article is reproduced from the Souvenir Volume published by Dr. K. S. Krishnan's Sixtieth Birthday Celebrations Committee, New Delhi. Originally published in J. Sci. Ind. Res., Vol. 14, 17A, Dec. 1958.

from all over India working in the Association under his unique leadership in various aspects of the subject. Krishnan entered into his work with great enthusiasm. He made a characteristically thorough experimental study of the scattering of light in a large number of pure liquids, worked on many problems in the classical theory of the diffraction of light and started work in the magnetic anisotropy of gaseous molecules and of crystals (nitrates and carbonates). He collaborated with Professor Raman in making a detailed examination of the change in the nature of the light which was found to be associated with molecular scattering. As is well known, these studies led to the discovery of the Raman Effect.

In October 1928, Professor Arnold Sommerfeld of Germany was a Guest Professor of the Calcutta University and he delivered a course of seven lectures on modern developments of quantum theory. Krishnan took careful notes of the lectures. As Professor Sommerfeld says, "the first three and the last two lectures were worked out by Mr. K. S. Krishnan in a very independent way." The lectures were later published by the Calcutta University.

Professor Krishnan was in the Dacca University from 1929 to 1933. With Dr. S. N. Bose as Professor of Physics and his old friend Dr. T. Vijayaraghavan, Reader in Mathematics, and with Mr. Langley as Vice-Chancellor, Mr. Krishnan found a congenial atmosphere in Dacca and threw himself heart and soul into his teaching and research activities. It was there that he developed his elegant and precise experimental methods to test out the idea that the magnetic anisotropy of a diamagnetic or paramagnetic crystal could be correlated with the anisotropy of the individual molecules and their relative orientations and that in favourable cases the precise orientation of molecules in the unit cell could be determined from magne-crystallic measurements. He worked out simple methods of measuring accurately feeble susceptibilities and anisotropies, making effective use of quartz fibre suspensions and liquid baths of varying susceptibilities for immersing the crystals. With his students, B. C. Guha, S. Banerjee and N. C. Chakravarty, he made measurements on a large number of crystals, both diamagnetic and paramagnetic.

The papers entitled "Investigations in magne-crystallic action", which were published in the next few years by Professor Krishnan and his students in the Philosophical Transactions of the Royal Society and in the Physical Review, are mines of information regarding the magnetic properties of diamagnetic and paramagnetic crystals. The work of Krishnan and his students and of Dr. Kathleen Lonsdale established the fruitfulness of magnetic methods as a valuable supplement to the methods of X-ray analysis for determining the architecture of crystals.

When Professor Raman left Calcutta in 1933, Krishnan was invited to take up the post of Mahendralal Sircar Professor of Physics in the Indian Association for the Cultivation of Science. There were no regular teaching duties attached to the post and a return to the old familiar cosmopolitan surroundings of 210 Bowbazar was welcome to Krishnan. The magnetic and optical properties of crystals together with their structure analysis by X-rays, and the various ways in which the anisotropy of crystal units manifest themselves in the bulk properties of the crystals continued to occupy his attention. To the second Calcutta period belongs the work of Krishnan, Bose and Mookherjee on the magnetic properties of salts of the rare earth and iron groups including a detailed comparison of their extensive experimental measurements with the conclusions which follow from the theoretical work of Van Vleck and Penney and Schlapp on the crystalline electric fields of such crystals. In paper V in the series on magne- crystallic action published in the Philosophical Transactions of the Royal Society, there is detailed discussion

of the susceptibilities and anisotropies of these crystals and of the conditions which determine to what extent the temperature variation of their susceptibilities will follow the Curie Law. To the same period also belongs a characteristically significant paper by Gangulee and Krishnan on "The magnetic and other properties of free electrons in graphite" (Proc. Roy. Soc., 1941). In this paper, the authors show that the diamagnetism of graphite is almost wholly along the hexagonal axis, that in a graphite crystal, one electron per carbon atom is free to move in the basal plane but not in a perpendicular direction, or in other words, the electrons in such a crystal form a two-dimensional electron gas, and that the theoretical properties of such an electron gas can be verified in detail from a study of the magnetic properties of graphite. From the measured values of the diamagnetism of graphite at different temperatures varying from —90 to 1270 K, they conclude that the energy distribution of electrons in graphite conforms to Fermi-Dirac distribution.

Professor Krishnan's contributions to physics were recognized by the invitations he received from Lord Rutherford in Cambridge and Sir William Bragg in London to give a course of lectures in the Cavendish Laboratory and in the Royal Institution (1937). He later visited a number of universities in Europe and was awarded the University Medal by the University of Liege for his scientific achievements. In 1939, he was invited to participate in an International Symposium on Magnetism at Strasbourg. Krishnan was elected to the Fellowship of the Royal Society in 1940.

In 1942, Krishnan was offered the post of Professor of Physics in the University of Allahabad which had been vacant for some years after the departure of Professor M. N. Saha to Calcutta. Krishnan always enjoyed teaching and discussion. The Professorship in Allahabad gave him an opportunity to review, in a systematic and comprehensive way, before senior students the various problems of classical scattering of light, X-rays and electrons, of statistical thermodynamics, and quantum theory and wave mechanics. Despite the difficult conditions created by the war, Krishnan and his associates were able to do a good amount of investigational work on these subjects. In particular may be mentioned his work with Dr. A. B. Bhatia giving a critical review of Einstein's theory of light scattering in homogeneous media as reflection from thermal elastic waves and a new and illuminating method of summing up the intensities of the elastic waves. They also treated on a unified basis the scattering of X-rays by fluids and of low velocity electrons by liquid metals and by alloys.

As an offshoot of the analysis of elastic waves in a homogeneous medium caused by fluctuations of density, Krishnan was led to the study of the mathematical problem of the summation of certain infinite series of a class of functions which are of special importance in physics. He showed that with functions whose Fourier transforms satisfy two simple conditions, the sum of the infinite series could be obtained just as well by rectangulation as by integration, and that this was not an approximate, but a rigorous result. Krishnan's paper "On the equivalence of certain infinite series and the corresponding integrals" in the Journal of the Indian Mathematical Society (Vol. 12, 1948) shows the range and power of the method.

Even before the gaining of independence, it was felt by many Indian scientists and statesmen that there was a great need for national laboratories in different branches of science and technology in India. With the achievement of independence, the Government of India decided to start such laboratories, and the laboratories for chemistry and physics were the first ones to be started. Professor Krishnan was offered the Directorship of the National Physical

Laboratory. Although the acceptance of this meant getting away from teaching and research, at least temporarily, Krishnan accepted the offer and took over the duties in 1947.

A good deal of Krishnan's time during the next few years was taken up in administrative duties and committee work, but still he was able to keep up active interest in scientific research. Evidence for this is found in his work with Dr. S. K. Roy on the frequencies and anharmonicities of alkali halide crystals and on a critical analysis of the difference between the characteristic frequencies which appear in the dispersion formulae of Drude and Lorentz. In the Drude formula, the frequencies are characteristic of the medium, and in the Lorentz formula, they are characteristic of the oscillators when unaffected by the polarization field. At about the same time, there began to appear a series of four brilliant papers on thermionics with Dr. S. C. Jain. Thermionics began to interest Krishnan when he was in Allahabad. He had suggested in 1944 a new method of determining the saturation pressure of electrons by effusion through a small aperture in a uniformly heated chamber of graphite whose inside could be coated with different materials. Like cavity radiation for the study of black body radiation, this method has several advantages. With the assistance of Dr. Jain, he started experimental work at the National Physical Laboratory and, in a few years, they were able to determine with great accuracy the thermionic constants of graphite, the metals of the iron group and of the monovalent metals, copper, silver and gold. In their final paper they discussed the energy barrier at the surface of a monovalent metal, on the thermodynamic potential of the electrons and on the work function in metals. They showed that the observed variation of the work function was as though the electrons in the metal and in the vapour formed the two phases of a single component thermodynamic system. They showed further that the thermal expansion of the lattice and the thermal agitation of the atoms in the lattice both affected the work function of the metal, but that the effects of the two practically cancelled each other.

Another problem which is of an applied physical nature and has engaged Krishnan's attention in the National Physical Laboratory is the distribution of temperatures along a thin rod (or wire) electrically heated in vacuo. In modern electrical technology, electrically heated wires find extensive use in various devices, such as electric lamps, valves of various kinds, cathodes of X-ray tubes, etc. The functioning and efficiency of these devices depend largely on the manner in which the temperature, and depending on it, other properties, are distributed along the wire. With the collaboration of Dr. Jain, Krishnan attacked this problem both from a theoretical and an experimental point of view. On the theoretical side, the authors formulated the appropriate differential equation and solved it in a practically usable form both for long and short filaments. On the experimental side, they carried out measurements on thin rods of Acheson graphite and platinum filaments, and verified the theoretical results. Moreover, they compared these theoretical results with the empirical findings of many investigators who had studied the subject before and found very satisfactory agreement. They thus brought orderly thinking into a complex but very practical subject and made the way easier for further advantages.

I have mentioned above only the major items of work in which Krishnan himself was engaged, for they bring out clearly his broad outlook, his carefulness in the choice of problems, the masterly combination of theoretical and experimental methods of approach, the depth, thoroughness and maturity of his treatment and the elegance of his presentation of results. I do not propose to discuss the various other studies and projects, both in the National Physical

Laboratory and elsewhere, in which he has taken interest and guided or helped. Scientists in India know how freely he gives of his knowledge and time. I should not, however, fail to mention his intimate, active and uninterrupted association with the Department of Atomic Energy from its very beginning.

Believing as Krishnan does that science alone cannot solve all problems in life, he combines an earnest study of the classics of Indian religious literature with the study and practice of science, and endeavours to live a life of religious faith. The combination of Vinaya (humility) with Vignyan (critical understanding), which has become natural to him, makes it easy for people of all sections in life to feel at ease in his company.

It is not surprising that Krishnan is much sought after for giving addresses and discourses not only on scientific but also on literary and philosophical subjects. He has great respect for Indian scholars of Sanskrit and other Indian languages who have been brought up in the traditional Indian way. Being himself a writer of distinction on philosophic and scientific subjects in Tamil, Tamil and Sanskrit scholars all over India and in Ceylon find him congenial and stimulating company, and take delight in inviting and honouring him at their conferences and assemblies.

Krishnan has been the recipient of many honours both in India and abroad. He is a past President of the Indian Science Congress, of the National Academy of Sciences and of the National Institute of Sciences. He is a Founder-Member of the International Union of Crystallography. He has been Vice-President of the International Union of Pure and Applied Physics and of the International Council of Scientific Unions. Krishnan's quick grasp of essentials and the brevity and lucidity of his exposition make him a respected member in international scientific meetings and assemblies.

In 1955, the U.S. National Academy of Sciences invited Krishnan to be their chief guest at their annual meeting as the representative of Indian Science. This is an honour which had been previously given to the President of the Royal Society, London the President of the Royal Netherlands Academy and the President of the Swedish Academy. At the ceremonial dinner of the Academy, Krishnan spoke on India's forward outlook on science and technology and also explained how that outlook was tempered by her own basic philosophy and sense of values. After the meeting, President Bronk wrote to Krishnan, "You did much to emphasize and strengthen the friendly bonds between scientists of your country and ours, and thus fostered the traditional international unity of science".

Next year, in 1956, Krishnan was elected a Foreign Associate of the National Academy of Sciences. This is a high honour indeed as the total number of Foreign Associates today is only 60, of whom 9 are physicists. In the same year, at the request of the All India Radio, Krishnan gave in Delhi the second series of Sardar Vallabhbhai Patel Memorial Lectures, taking as his theme "The New Era in Science".

The Government of India recently honoured Krishnan by appointing him a National Professor—an honour which he shares with Professor C. V. Raman and Professor S. N. Bose. The whole country wishes Krishnan many years of active happy life, searching, learning and teaching in his own quiet and confident way.

Sir K. S. Krishnan & the International Geophysical Year

SYDNEY CHAPMAN

President, Special Committee for the International Geophysical Year, Brussels

It is a pleasure to take part in the celebration of the sixtieth birthday of my distinguished friend and colleague Sir K. S. Krishnan, F.R.S., by contributing to this special volume. Such a volume on this occasion is a fitting tribute to the high distinction he has won as a scientist and administrator, and to the many services he has rendered to science and to his country and to the community of nations. His personal scientific researches have been recognized by the conferment upon him of many high honours. As a teacher he has fostered the scientific spirit and enthusiasm of his country's youth. As Director of a great scientific institution he has furthered the scientific and economic advance of India.

Here, however, I would specially write of his association with that remarkable worldwide scientific enterprise—the International Geophysical Year (IGY) 1957-58. Only his colleagues on the National IGY Committee for India can fully know the leadership and the support he has given, as President of that Committee, in developing India's IGY participation and programme. But the scope and excellence of that programme redounds to his credit, which he will be the first to wish to share with his many distinguished fellow officers and colleagues on the Committee and with the still greater number of his countrymen and countrywomen who are taking a direct personal part in the programme.

Sir K. S. Krishnan has not only led and supported the plans for India's share in the IGY, he has also given it valuable support on the international level, in his capacity as Vice-President of the International Council of Scientific Unions (ICSU) for the past six years. This eminent position has given him a voice in the formation and progress of the Special Committee for the International Geophysical Year (CSAGI)—Comite Special de l'Annee Geophysique Internationale—over which I have had the honour to preside. As a leading member of the Bureau of ICSU he has shared the executive responsibility resting on that Bureau for the multitudinous scientific affairs associated with ICSU; and not least as regards the IGY and the reports by CSAGI to ICSU, his scientific knowledge and experience have fitted him to give counsel solidly based.

To turn now to the IGY programme of India, it is good to record that India took part in every one of the fourteen divisions of the international programme. The Meteorological Department of India, as one of its many valuable contributions to the programme, received the notices of Alerts and Special World Intervals, and relayed them to All India Radio to be broadcast at specific times of the day. These broadcasts included a daily report on the sun's activity, received

1. From collected works of K.S. Krishnan, Published by N.P.L. New Delhi, 1988

from the Kodaikanal Observatory. This observatory was an important member of the chain of solar stations that girdle the earth, whose regular programmes of observation were extended and intensified during the IGY—so that the sun was then observed with a degree of completeness and detail never before approached. The Nizamiah Observatory. Hyderabad, also contributed to this achievement, by its observations of solar flares.

The India Meteorological Department played an active role in its own most distinctive sphere, as a member of the World Meteorological Organization (WMO) in the execution of India's part in the meteorological IGY programme drawn up jointly by CSAGI and WMO. It gave valuable support also to the IGY auroral programme, by directing ten of its stations to watch regularly for the aurora at specific times. Its exploration of the atmosphere by balloons included, besides the usual meteorological elements, the measurement of the electrical potential gradient and electrical conductivity of the air.

In geomagnetism the same Department extended its normal observatory recording by the maintenance of additional stations at Trivandrum and Chidambaram, supplementing the permanent magnetic station at Kodaikanal, to study the equatorial electrojet. Projects related to the World Magnetic Survey that is to form a deferred part of the IGY were carried out by the Survey of India and the Hydrographic Department of the Indian Navy.

The IGY airglow programme of observation was advanced by observations at four stations. Mt Abu, Gulmarg, Dharwar and Poona. The cosmic ray neutron programme was executed at four stations, Ahmedabad, Kodaikanal, Gulmarg and Darjeeling, and there were cubical meson telescopes at five stations, and ionization chamber studies at Howrah. The Physical Research Laboratory at Ahmedabad (Director, Professor K. R. Ramanathan) took an active part in the airglow and cosmic ray programmes, and also in the WMO scheme of ozone studies—in which India employed no less than six Dobson spectrophotometers.

The many-sided IGY ionospheric programme was very actively undertaken in India, with eight observatories for vertical incidence recording. The pre-IGY measurements of ionospheric drift were extended by an additional station, making four in all. Absorption measurements were also made at four stations.

The Survey of India and the National Physical Laboratory co-operated in the programme of Latitudes and Longitudes, including the use of a Danjon impersonal astrolabe and a Markowitz moon camera.

Three glaciers, at Gangotri, Shigri and Machhoi were re-visited and studied after 57 years, by the Geological Survey of India.

The Survey of India extended its oceanographic activities, among other ways by increasing the number of its normal tidegauge stations from fifteen to twenty-one. The India Meteorological Department made associated observations at each tide station.

India took part in the IGY satellite tracking programme by means of a Schmidt precision camera installed at the Uttar Pradesh State Observatory at Naini Tal; the camera was a gift from the Smithsonian Astrophysical Observatory at Harvard.

India co-operated also in the IGY programmes for seismology, earth tides, gravity measurement and nuclear radiation.

In this connection I would like to recall a fine passage of the Presidential Address of Sir K. S. Krishnan's friend and colleague, Professor K. R. Ramanathan, given at the opening Assembly of the International Union of Geodesy and Geophysics at Toronto, on 3 September 1957.

"The ICSU and the CSAGI have done a great job. The greatest single achievement of organized science in history was perhaps the building of the first atom bomb. It required the bringing together of many top-ranking scientists, technologists and organizers on an unprecedented scale. But they were top-ranking men, and of a few countries only. The IGY is in my view an undertaking of greater magnitude and difficulty, because it has involved the bringing together of workers of many nations with differing ideologies and in very varying stages of scientific development. A keen, diligent observer with modest education in any corner of the world has a respected place in the IGY scheme. The approach is human and earthy, and the potentialities for the unification of mankind are infinitely greater."

Among Dr. Krishnan's many other achievements that will be recalled in this birthday celebration, the part he has played in this great enterprise of the IGY must not be forgotten.

Kariamanikkam Srinivasa Krishnan[1]
1898-1961
Foundation fellow 1935

KATHLEEN LONSDALE and H. J. BHABHA

INDIA lost a distinguished physicist and philosopher in the death, after a third heart attack, of Kariamanikkam Srinivasa Krishnan. His contributions to science and his achievements especially in physics won international recognition for India.

Krishnan was born on 4 December 1898, in the village of Watrap, in the Tirunelveli (now Ramnad) District of Tamilnad (Madras State). His father was a Brahmin farmer-scholar of the old school, deeply versed in Tamil and Sanskrit religious literature, who spent a good part of his time in pilgrimages to South Indian temples, particularly to Srirangam and Tirupathi. From him Krishnan inherited an abiding love of religion and philosophy and a thorough knowledge of the Tamil language and literature, and of Sanskrit. His mother was very intelligent and an excellent organizer.

His early schooling was in the rural surroundings of his native village and at the Hindu High School at nearby Srivilliputtur. In a broadcast talk on All India Radio he once described the palm- leaf manuscript of which, in the first standard, two or three leaves were written every day until by the end of the year it had become a good-sized 'book' containing a vast amount of general information. It included, among other things, formulae for identifying the constellations in the night sky and mnemonics for determining time from the position of the constellation nearest to the zenith. This, he said, was not merely book knowledge but was accompanied by actual observations on the night sky. It was typical of Krishnan's encyclopaedic memory that late in life, when confronted with a question on astronomy, he was able to give a convincing answer from his recollection of the palm-leaf manuscript.

His subsequent education was partly in the American College, Madura, and then in the Christian College, Madras, where, after taking his degree. in physics, he became a Demonstrator in Chemistry. He was meticulous in seeing that every fresh student knew exactly how to make observations and how to record the results of experiments. In later life he himself took much trouble to write both tersely and lucidly. At the request of some of the students he began an informal lunch-hour discussion to which they could bring any questions in physics, mathematics or chemistry. After a time so many students came from other Madras colleges than even the big gallery of the lecture room was full to overflowing. One of his students, who afterwards became Principal of Andhra University College, Waltair, has written: 'I learnt more physics in that half an hour in Krishnan's class than during the rest of the regular lectures, as his explanation of physical concepts was wonderfully lucid'. He was also much loved for his kindly and sympathetic manner.

1. Reproduced from the Biographical Memoirs of the Fellows of the Royal Society, Volume 13, 1967.

In 1920 Krishnan went to Calcutta, attracted by the fame of the growing school of physics being developed by Professor C. V. Raman at the University College of Science, There he attended post-graduate classes, but showed such a keen interest in and aptitude for research in optics and molecular physics that Raman, realizing Krishnan's abilities, took him as a Research Associate in the Indian Association for the Cultivation of Science, 210 Bowbazar Street, where he at first lived with other young research workers in the dormitories. Here, it was said, he could hold his room-mates spell-bound with tales from the epics and of the ancient saints and philosophers. His day in the laboratory began, at 6 a.m., often after an early walk and a cold bath. As he was a great football fan, many an evening would be spent with his colleagues watching a match in the Eden Gardens. He also used to take a very lively interest in political movements and personalities, and was a strong nationalist. At one time he thought it unbecoming to go abroad in search of Western learning and even took to writing his scientific papers in Tamil; but time mellowed him in this respect (although he always retained a spirit of sturdy independence of thought and action) and he grew to love Western literature. He was a voracious reader all his life and afterwards said (in the broadcast previously mentioned, published in the Souvenir in honour of his 60th birthday, 1958):

Walter Scott, Dickens, Thakeray, Stevenson, Cervantes, Dumas and Victor Hugo and Conan Doyle linger in my memory as my favourite authors at this time, Plato and Aristotle in translations, Shakespeare, Milton and Shelley, Swift, Addison, Boswell, Newman, Matthew Arnold, Walter Pater and Charles Lamb at a later age and Tolstoy, Ibsen and Bernard Shaw still later. Some of them naturally stand out much more prominently than others in my memory. I should specially mention Don Quixote, Pickwick Papers, Vanity Fair and Book of Snobs, Essays of Elia, Essay and Discourses of Stuart Mill, some of the prose writings of Swift and Whitehead, Alice in Wonderland and Through the Looking Glass, most of which I have re-read later.

'Among the popular scientific books that made a great impression on me I should specially mention Tyndall's Fragments, Microbe Hunters by Paul de Kruif, Men of Mathematics by Eric Bell, A Mathematician's Apology by Hardy, and the biographies of Kelvin, Helmholtz, Lord Rayleigh, Maxwell and Tait.'

'Among the serious scientific writings, the collected papers of Lord Rayleigh have been my constant companion for 38 years and I cannot think of a better model for a research worker. One of the research papers of Einstein I have read off and on during the same period, and every time I read it I get something new out of it. Some of the papers of Niels Bohr had over me even more profound influence.'

All this he could take in his stride without the least interruption to the quality or quantity of his scientific work. Given the opportunity by Professor C. V. Raman, who was a source of great inspiration to all his students, Krishnan plunged deeply into an experimental study of the scattering of light in a large number of liquids, and its theoretical interpretation; he also began work on the magnetic anisotropy of gaseous molecules and of crystals (nitrates and carbonates). He collaborated with Raman in making a detailed examination of the changes in the frequency and polarization of light which was found to be associated with molecular scattering. These concentrated studies led to the discovery of the Raman effect in 1928.

In October 1928 Professor A. Sommerfeld visited Calcutta and gave a course of seven lectures on 'Modern developments in wave mechanics'. Krishnan took careful notes and

undertook the task of preparing the lecture course for publication by Calcutta University as a book. In so doing he developed five of the lectures in an independent way and was commended by the visiting Professor for his originality and scholarship in supplying elegant mathematical proofs.

From 1929 to 1933 Krishnan served as a Reader in Physics at Dacca University where he found a very congenial atmosphere for teaching and research, with Professor S. N. Bose as Head of the Physics Department. Here he turned his attention to this subject of magnetic properties of crystals in relation to their structure, and developed elegant and precise experimental techniques to measure the magnetic anisotropy of dia- and paramagnetic crystals. He was able to correlate the anisotropy of crystals with the anisotropy and arrangement of the individual molecules or ionic groups. In suitable cases, from magne- crystallic measurements, the orientation of molecules in the unit cell could be determined. Krishnan and his students also developed methods for the accurate measurement of feeble susceptibilities and anisotropies. The papers he published during this period in collaboration with B. C. Guha, S. Banerjee and N. C. Chakravarty were the foundation stones of the modern fields of crystal magnetism and magneto-chemistry.

Krishnan was invited in 1933 to take up the post of Mahendralal Sircar Professor of Physics in the Indian Association for the Cultivation of Science, Calcutta. This infused in him a new enthusiasm and a fresh impetus. With Mookherji and Bose as co-workers, he continued vigorously the study of the magnetic properties of the salts of the rare earth and iron groups and integrated the results of measurements on the crystalline electric fields of crystals with the theoretical conclusions of Van Vleck, Penney and Schlapp. Many of his papers on magne-crystallic action were published in the Philosophical Transactions of the Royal Society. At about the same time, Ganguli and Krishnan, in a classic paper in the Proceedings of the Royal Society (1941), established that the diamagnetism of graphite is very large indeed along the hexagonal axis and that certain of the electrons in such a crystal form a two- dimensional electron gas. Further, from the temperature-variation study, they concluded that the energy distribution of electrons in graphite obeyed Fermi-Dirac statistics.

The outstanding achievements of Krishnan could not remain unnoticed. He was invited by Lord Rutherford to the Cavendish Laboratory, Cambridge, and by Sir William Bragg to the Royal Institution, London, to give course of lectures in 1937. The Liege University Medal was awarded to Krishnan as a recognition of his scientific achievements.

Krishnan became the Professor of Physics in the University of Allahabad in 1942. Here he was concerned with teaching and research. In discussion with senior students, he reviewed in a systematic way various problems of the classical scattering of light, X-rays and electrons, of quantum theory, wave mechanics and statistical thermodynamics. Together with his students, he was able to carry out some important investigations in these subjects in spite of administrative duties and war-time difficulties.

Krishnan undertook a theoretical investigation in collaboration with A. B. Bhatia on the electrical conductivities of metals and alloys. He found that the scattering of electrons can be almost wholly attributed to local thermal fluctuations in density of the type studied by Smoluchowski and Einstein. This study could be easily extended to binary alloys also. In the case of alloys, the large increase in the resistivity due to alloying was shown to be due to

fluctuations in the concentration of the alloying metal rather than to fluctuations in density. With this, a simple approach was found for discussing the electrical properties of metals and alloys as order-disorder phenomena.

Then came independence for India and its new leaders saw in Krishnan an outstanding senior scientist of international reputation. He was offered the Directorship of the National Physical Laboratory, New Delhi, which he accepted, though it meant sacrificing his natural desire for teaching. The post carried with it large administrative responsibilities. These did not deter Krishnan from continuing his activities in his chosen fields of research. With S. K. Roy, he analysed the differences between the characteristic frequencies which appear in dispersion formulae and published a series of papers in the Proceedings of the Royal Society and elsewhere which resolved certain doubts regarding the original formulae of Drude, and Lorentz and gave many new and significant results.

At the National Physical Laboratory Krishnan also turned his attention to problems in the thermionics in collaboration with S. C. Jain. He suggested a new method of determining the saturation pressure of electrons by passing them through a small aperture in a wall of a uniformly-heated graphite chamber whose inside could be coated by any metal. This was a new technique which avoided the need for degassing the surface of a metal and, at the same time, allowed the determination of the thermionic constants and their temperature coefficients. In particular, the data for the monovalent and transition metals present some interesting features in as much as the method is analogous to that of obtaining black-body radiation which is independent of the emissivity of the walls of the chamber.

He devoted both theoretical and experimental attention to the study of the distribution of temperature along a thin rod or wire which is electrically heated in vacuo. The temperature distribution was found to be parabolic near the centre, logarithmic a little farther away and approximately similar to that of an infinitely long filament near the ends. These studies have a practical application to modern industry in connection with electrical technology.

The problem of temperature distribution along a heated tube was also solved by Krishnan and Sundaram. They calculated, in a straightforward way, the radiative transfer of energy in the hollow core of the tube. The expression they obtained bears a close similarity to that of the lattice conductivity of a dielectric cylinder at very low temperatures, in which the diffusion of the phonons is responsible for conduction and their free path is also determined, as in this case, by the diameter of the cylinder.

In the last few years of his life he gave much thought to obtaining an integrated picture of the problem of the solid state.

Krishnan loved mathematical reasoning and his skill as a mathematician would have gained him international recognition even without his great ability as an experimental physicist. He was deeply moved by a by-product of pure mathematical interest thrown up during the course of a physical investigation. At the same time, although a pure scientist himself, he strongly deprecated any division between pure and applied mathematics or science and when, in 1955, the U.S. National Academy of Sciences invited him to be the guest speaker at their Annual Dinner (a privilege that only the Presidents of the Royal Society, of the Royal Netherlands Academy and of the Swedish Academy had previously enjoyed) he seized the opportunity of extolling the purely cultural values of technological training and showed how India was trying

to improve this aspect of her national life. Professor Van Vleck said afterwards of his speech: 'He quoted extensively from Whitehead and it was his speech that prompted me to read some of Whitehead's writings'.

Krishnan also believed firmly that international cooperation in science was one of the best ways of promoting understanding between nations and he was himself an ideal ambassador for India because his humility, simplicity and humour, combined with his scientific and cultural erudition and an all-too-rare fund of common sense won him friends all over the world. He never lacked an appropriate anecdote with which to drive home a moral or disarm a critic, or just to entertain. Nehru once remarked that he did not remember meeting Krishnan on any occasion when he had not told him some new story. But Nehru also said of him on his sixtieth birthday: 'He is a great scientist, but something much more. He is a perfect citizen, a whole man with an integrated personality.'

Krishnan was the recipient of many honours both in India and abroad. He was elected a Fellow of the Royal Society, London, in 1940 and was knighted in 1946. He was associated with the work of many national and international scientific bodies: Chairman, Scientific Advisory Committee, UNESCO; Vice-President, International Council of Scientific Unions and of the International Union of Pure and Applied Physics; Chairman, Indian National Committee, URSI; Chairman, Indian National Committee for IGY and Chairman, Sub-Commission for Cooperation with UNESCO. He was, with P. P. Ewald, M. v. Laue and W. L. Bragg, a Founder- Member of the International Union of Crystallography, and afterwards a member of its Executive Committee. In 1956, Krishnan was elected a Foreign Associate of the U.S. National Academy of Sciences; in 1959 he was the guest speaker at the Geneva Convention of the International Telecommunications Union.

Dr. Krishnan had an active association with the work of many scientific organizations and establishments in India. He was President, Section of Physics, Indian Science Congress in 1940 and its General President in 1949. He was President also of the National Academy of Sciences and of the National Institute of Sciences. He was the Chairman, Board of Research in Nuclear Science, Member, Atomic Energy Commission, Board of Engineering Research, Standing Board of Astronomy and the University Grants Commission. He served the Council of Scientific and Industrial Research from its very inception in various capacities, as a member of the Governing Body and the Board of Scientific and Industrial Research, and on many of its Research Committees. As a member of the Editorial Board, he contributed significantly to the growth and progress of the Journal of Scientific and Industrial Research.

The title of Padma Bhushan was awarded to him by the President of India in 1954, and he was the first recipient of the Bhatnagar Memorial Award in March 1961. The government of India honoured Krishnan by appointing him a National Professor—as honour which he shared with a very few great Indian scholars. But he did not live long to enjoy this honour. Just before he died he was planning to take the first long leave of a lifetime, to visit a son in England and a daughter in the U.S.A., whose little son he had never seen. He loved playing with his grandchildren at home.

He left behind him his wife, two sons and four daughters.

(The first draft of this was prepared by the late Dr. H. J. Bhabha, F.R.S., and was found amongst his papers late in 1966.)

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PROF. K. S. KRISHNAN, F.R.S.–A PROFILE[1]

R. SUNDARAM

'Physics means facing facts', Prof. Krishnan said during my first meeting with him. I had gone to him after taking a degree in mathematics, seeking a research problem. He knew that persons 'trained in pure mathematics are prone to talk in terms of generalizations. He warned me about the possible dangers of attacking a problem in all its generality. He preferred cases to be worked out first. When I recollect today, Prof. Krishnan reminds me of Prof. E. P. Wigner, whose biography I have had occasion to read.

In this account, I shall try to draw a profile of Prof. Krishnan. This is a study, though disjointed, of his approach to things in general and physics in particular, by one of his research students.

Prof. K. S. Krishnan or Sir K. S. as he was fondly referred to by friends, took over the directorship of the National Physical Laboratory in 1948. The new building was ready by 1950. On one of those early days, once when Sir K. S. was standing near the main entrance, a USA-trained young scientist approached him with a request to visit the laboratory. He did not know who Dr. Krishnan was. Sir K. S. took him round the laboratory, explained to him every aspect of the work to be undertaken, but not once did he reveal his identity. The swank and superior airs of the young man were in such bounteous measure that he refused to discern the enlightened conversation of Sir K. S. At last, Sir K, S. brought the youngman to the room marked 'Director' and said 'This is my room'. The chinks in the armour of the youngman were then visible and he was profusely apologetic. That was the typical Krishnan style of humbling arrogance. There was something Gandhian about it.

Sir K. S. even though Director of the Laboratory was accessible to everybody. On one occasion, when I was having discussion with him on a research problem, one of the Class IV employees entered his room and started narrating his grievances. Sir K. S. listened to him for full fifteen minutes. His grievance was redressed within three days. As Director, Sir K. S. could have remained in the hilltop with lot of hurdles placed on the way up, as was the practice of the Directors of many other institutions, but he was so gentle and humane that he refused to be a bureaucrat. This tradition in NPL, set up by Sir K. S. has been followed by all the Directors who have succeeded him.

Sir K. S. was almost the first to arrive in the laboratory every day. By about 8.30 A.M., he was already looking into the research problem in hand and invariably his research student was also there. His presence evoked a sense of respectful fear, instead of fearful respect. The interaction (between Sir K. S. and the student) which lasted for two hours before the hustle and bustle of the laboratory started, was a rare experience, the frequency of which never made it stale. One could do loud thinking with him; in fact, he liked you to do so; but then, one had

1. Published in J. Phy. Education, Vol. 3, P. 8-9, Dec. 1975

to be prepared for facing his incisive logic and ruthless criticism. Sir K. S. was essentially a great critic. At the same time, he had deep respect, almost bordering on blind faith, in the established works of eminent physicists of the earlier era, that if anyone pointed out even the minutest shortcoming of these works, he took it as a personal affront. One occasion is worth recalling. The BCS theory of superconductivity appeared in the Physical Review in 1957. Sometime in 1958, we had requested Prof. D. S. Kothari and Prof. F. C. Auluck to address the NPL colloquium on the BCS theory. What we witnessed on that day was something like an encounter between two great giants, Sir K. S., a vigorous supporter of the London's theory and Prof. Kothari, an ardent votary of the new microscopic theory of BCS. The discussion centered around the derivation of the Meissner effect, which follows directly from the London equation.

$$j(x) = -\frac{1}{c\,\Lambda} A(x), \quad \Lambda = \frac{4\pi \lambda_L^{\,2}}{c^2}$$

where j is the current density; A is the vector potential; and λ_L is the London penetration depth.

However, to derive Meissner effect from the BCS model, one had to do a lengthy calculation. Sir K. S. was not easily convinced of the pairing interaction. I may add that, perhaps, the discovery of flux quantization i.e.,

Φ, magnetic flux through a ring

$$= integer \times \frac{hc}{2e}$$

and its beautiful experimental verification (specially of the factor $^1/_2$) by Deaver and Fairbank, and Doll and Nabauer would have convinced Sir K. S. of the correctness of the BCS pairing in the ground state. The repo rt of this verification appeared only in July 1961, but by then Sir K. S. was no more.

In this context. I would like to make a general comment on the progress of Physics; From the late fifties, Physics has progressed very fast, since Quantum Field theory had offered many new techniques for handling many-body problems. The problems in Solid State, which are many-body problems could be solved by these advanced methods. The transition to this new era in Physics is similar to the transition from Mathew Arnold's prose to Keat's poetry in English literature. In Mathew Arnold's prose it is the ideas which are primary and the language in which they are clothed is secondary. In Keat's poetry it is the idea-packed language. For example, in the new era in Physics, poles of a Green's function give the excitations of a system and singularity in T-matrix gives phase transition and so on. The power and potentialities of the new method's are tremendous. Sir K. S, did not live long to see these advances, although he had a glimpse of it in the BCS theory.

No account on Sir K. S. will be complete without mention of his versatile knowledge in physics. He could comment with a high degree of excellence in almost all areas of physics. All the same, his approach to higher knowledge was marked with humility. On one occasion, when Prof. Norbert Wiener of Cybernetics fame had finished his talk on 'Ergodic Theory' in our NPL colloquium, he requested Sir K. S. to give his impression on the progress of Ergodic Theory;

Sir K. S. said 'I do not know. That is not my area.' In scientific circles abroad, he was considered a complete physicist, an honour which he shared with Sir Rayleigh. He was also a man of great erudition in Sanskrit and Tamil classics.

Sir K. S. was very fond of travel. He once mentioned that his hobbies were travel, tennis and tamil classics. In fact, his first heart-attack can be attributed to his frequent travels. Even while travelling he used to work on scientific problems. Once, while going to Bangalore, he asked me to accompany him upto the aerodrome. During the car drive, he asked me to tell him all the properties of Gamma and Beta Functions. In the aerodrome, he said, 'Let me think over these functions in my journey. On my return, we will discuss more about them.' An year later, on a similar occasion, the story turned out to be different. On the last day he spent in the laboratory, we had met for fifteen minutes we talked Fermi surfaces of metals. On the next day, he was to fly to Bombay. He told me, 'May be we can discuss more on my return' 'May' includes 'May not', as they say. It was like a premonition. He had another heart-attack at night which proved fatal. I always remember Prof. K. S. Krishnan with the highest regards, as he was my Guru who readily accepted me as his student, taught me, controverted me and above all, created holy curiosities in me.

He must have had an unshakeable faith in the famous quotation from *Proverbs XVI,* 16.

'How much better is it to get wisdom than gold. And to get understanding rather to be chosen than silver' for, how else, could he have pursued Physics till the last day of his life ?

THE DIAMAGNETISM OF THE MOBILE ELECTRONS IN AROMATIC MOLECULES

K. S. KRISHNAN, D.Sc., F.N.I., F.R.S.[1]

Considerable progress has been made during recent years in our understanding of the structure of aromatic molecules, and in particular of benzene. Much of this progress is due, on the theoretical side, to the application of quantum mechanics to study the nature of the linkage between the carbon atoms in the benzene ring and the part played by the valency electrons in the linkage, and on the experimental side, to the detailed investigations on the Raman and the infra-red spectra of benzene and its deutero-isomers, which have established the symmetry properties of benzene and the nature of its vibrations. One important result that emerges from these structural studies on benzene is that one electron in each atom in the ring is mobile and is more or less to migrate from atom to atom over the whole of the ring, a result of great significance to the sixty-year-old controversy regarding the location of the extra bonds in the benzene ring.

These mobile electrons have interesting magnetic properties, and I propose in this address to discuss some of these properties. In many respects the magnetic behaviour of these electrons is not dissimilar to that of the free electrons in metals, and the theoretical treatment in the two cases follows nearly the same course. I shall therefore deal first with the properties of free electrons, which are simpler.

The Paramagnetism of an Electron Gas

All the characteristic properties of a metal are explained satisfactorily on the assumption that a certain number of electrons get detached from their atoms and are free to migrate from atom to atom throughout the metal. Taking for example the alkali metals, there is considerable evidence from their optical properties, their Hall coefficients, the fine structure of their emission spectra in the soft X-ray region, theoretical studies on metallic cohesion, etc., to show that the number of such free electrons should be just one per atom. The paramagnetic properties of these electrons, regarded as forming a free- electron gas, are easily investigated. In the magnetic field the spin-moments of the electrons will place themselves either parallel or anti-parallel to the field, the number with parallel orientations *prepondering*, because of their lower energy in the field. Assuming that the preponderance of the parallel spins over the anti-parallel ones is determined by the classical statistics of Boltzmann, the susceptibility per unit volume of the gas will be given by the Curie law

$$\kappa_p = \frac{n\mu^2}{kT}, \qquad (1)$$

1. Presidential address to the Physics Section of the Indian Science Congress, Madras, delivered on Jan. 4, 1940.

where n is the number of electrons per unit volume, μ is the Bohr magneton, and the other letters have their usual significance.

In order, however, that the classical statistics may be applicable, the uncertainty Δq in the location of the position of the electron, which is determined by the Heisenberg relation

$$\Delta q \approx h/\Delta p \approx h/(mkT)^{1/2}$$

should be much less than the average distance between neighbouring electrons in the metal, namely $n^{-1/3}$. This would be the case only at temperatures much higher than

$$T_o \approx \frac{h^2 n^{2/3}}{mk}$$

For the alkali metals, with the number of free electrons equal to one per atom, this temperature will be of the order of 10^5 degree. Hence at all ordinary temperatures the electron gas in these metals will be almost completely degenerate, and the electrons will occupy, in pairs with opposite spins, all the energy levels permitted by Pauli's Exclusion Principle, up to $E \approx kT_0$. A few stray electrons having energies near about kT_0 will occupy their energy levels singly. To put it more precisely, the energy distribution of the electrons will conform to the statistics of Fermi and Dirac.

Now it is only the few stray electrons which occupy their energy levels singly, that can orient in the magnetic field and contribute to the magnetic moment. Their number, n' per unit volume, will obviously be much smaller than n roughly in the ratio of T to T_o, and the susceptibility will therefore be given by the expression

$$\kappa_p = \frac{n' \mu^2}{kT} \approx \frac{n \mu^2}{k T_o}$$

This gives the order of magnitude only. Detailed calculation given for the spin-susceptibility of the degenerate gas

$$\kappa_p = \frac{3}{2} \frac{n \mu^2}{k T_o}, \qquad (2)$$

where T_0, the degeneracy temperature, is given by

$$T_o = \frac{h^2}{8 mk} \left(\frac{3n}{\pi} \right)^{2/3} \qquad (3)$$

This in outline is the celebrated explanation given by Pauli for the feeble, temperature-independent paramagnetism exhibited by the alkali metals, which initiated the modern theories of the properties of electrons in metals.

The Diamagnetism of a Free-Electron Gas on the Classical Theory

That on the pure classical theory a free-electron gas should have no diamagnetism at all, seems to have been first demonstrated by Bohr. This result is at first sight surprising, since in the magnetic field the electrons will all describe paths whose projections on a plane perpendicular to the direction of the field will be circles, and the direction of motion in all the circles will be the same, and such as to give a negative moment along the direction of the field. On more careful consideration, however, it will be seen that the outer electrons in the medium which are too close to the boundary wall to execute complete circles will be reflected repeatedly from the wall, as shown in the diagram, (in which the boundary is assumed to be cylindrical).and will describe cuspidal paths; obviously this is equivalent to a creeping of these electrons along the boundary wall in a direction opposite to the direction of motion of the inner electrons. Though the creeping will be slow, yet because of the very large orbits in which these electrons creep, their contribution to the magnetic moment will be considerable, and on calculation we find that it exactly neutralizes the diamagnetic contribution from the inner electrons.

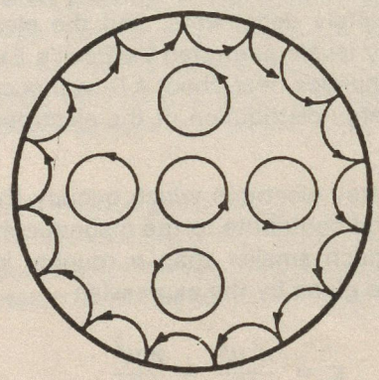


Fig. 1

This null result is independent of the nature of the boundary; in fact the boundary may be removed altogether. The result is even more general, and is applicable, as Miss vau Leeuwen has demonstrated, not only to an electron gas, but to any dynamical system obeying pure classical statistics. The success of Langevin's apparently classical theory of diamagnetism, which explains so elegantly the diamagnetic properties of atoms and molecules, is due to the initial assumption of well-defined electronic orbits, which is a quantum result.

Landau's Discovery

To Landau we owe the discovery that if the motions of the free electrons in the magnetic field are quantized, as they should be according to our quantum mechanical ideas, the balancing between the diamagnetic moments of the inner electrons which execute uninterrupted paths, and the apparently paramagnetic contributions of the boundary electrons, is disturbed, much in favour of the former, and the result is a large diamagnetic moment. The argument by which the result is deduced is somewhat difficult to appreciate intuitively, and I shall therefore merely quote Landau's result, which has been checked by others, and with other models too. The diamagnetism of the free electron gas is found to be just one-third of its spin-paramagnetism,

whatever the temperature may be, i.e. whether the gas is degenerate or non-degenerate. In other words, the diamagnetic susceptibility at high temperatures, $T > T_0$, should conform to the Curie law

$$\kappa_d = -\frac{n\mu^2}{3kT}, \tag{4}$$

and at low temperatures, $T < T_0$, when the gas is degenerate, the susceptibility should have the temperature independent value

$$\kappa_d = -\frac{n\mu^2}{2kT_o}, \tag{5}$$

The diamagnetism is of course superposed on the spin-paramagnetism, which will predominate, and the resultant susceptibility will be given by

$$\kappa = \kappa_p + \kappa_d$$

Experimental Verification of Landau's Diamagnetism

It would be of great interest to verify experimentally Landau's result, which is essentially a quantum result and has no counterpart in the classical theory. There are, however, two serious difficulties in verifying this diamagnetism, firstly the predominant paramagnetism with which it is normally associated, and secondly the enormous degeneracy temperatures for the free electron in most metals, 10^4 to 10^5 degrees, which render only the degenerate state accessible for experimenting. There is, however, one substance in which, owing to certain special conditions, both these difficulties are eliminated. I mean the crystal of graphite.

Graphite is a hexagonal crystal with a perfect basal cleavage,. The carbon atoms in it are arranged in layers parallel to the basal plane, the atoms in each layer forming a regular hexagonal network. The binding between neighbouring layers is extremely loose, and is probably of the Van der Waals type, as is evidenced by the very large distance of separation between them, viz., 3-4 A.U., as compared with the distance of 1.42 A.U. between adjacent atoms in the same layer. Three of the electrons in each carbon atom will be utilized in binding it to its three neighbours in the basal plane, and the fourth will be practically free to migrate from atom to atom in the basal plane, much in the same manner as the free electrons in a metal. The probability of the electron jumping to the next layer will be very small.

The conditions obtaining in graphite are very favourable for a verification of the Landau diamagnetism. With a magnetic field incident along the hexagonal axis, we are concerned with the motions of the electrons in the basal plane only, and these motions, as we have seen, are free; the diamagnetic properties of the medium will therefore be similar to those of a free-electron gas. The restriction of the freedom of the electrons practically to the basal plane actually proves to be an advantage; the restriction will be equivalent to an enormously increased effective mass for the electron for motion along the normal to the plane, and as a result the spacing of the energy levels along this direction will become much narrower, and hence the degeneracy temperature much smaller, than for electrons that are free to move in all directions.

Lastly, the spin-moments of the electrons in graphite are paired in such a manner as to give zero paramagnetism.

Experimentally, graphite crystal does have an abnormal diamagnetism, which is confined to the direction of the hexagonal axis (the susceptibility in the basal plane being practically the same as that of diamond), and which conforms to the Curie Law (4) at high temperatures, and to the temperature-independent value (5) at low temperatures, with the number of free electrons n equal to one per carbon atom and the degeneracy temperature T_0 = 520°K. At all temperatures (in the range investigated) the diamagnetism per carbon atom is found to be the same as the Landau diamagnetism per electron of a free-electron gas having a degeneracy temperature of 520°K. The theoretical values for the specific susceptibility (per gm.) of graphite calculated on this basis are represented by the curve drawn in Fig. 2. The straight line which the curve tends to reach asymptotically at high temperatures, namely that corresponding to the Curie Law (4), is also drawn in the figure. The circles denote the experimental values obtained by Mr. Ganguli and the present writer, and it will be seen that they all lie close to the theoretical curve.

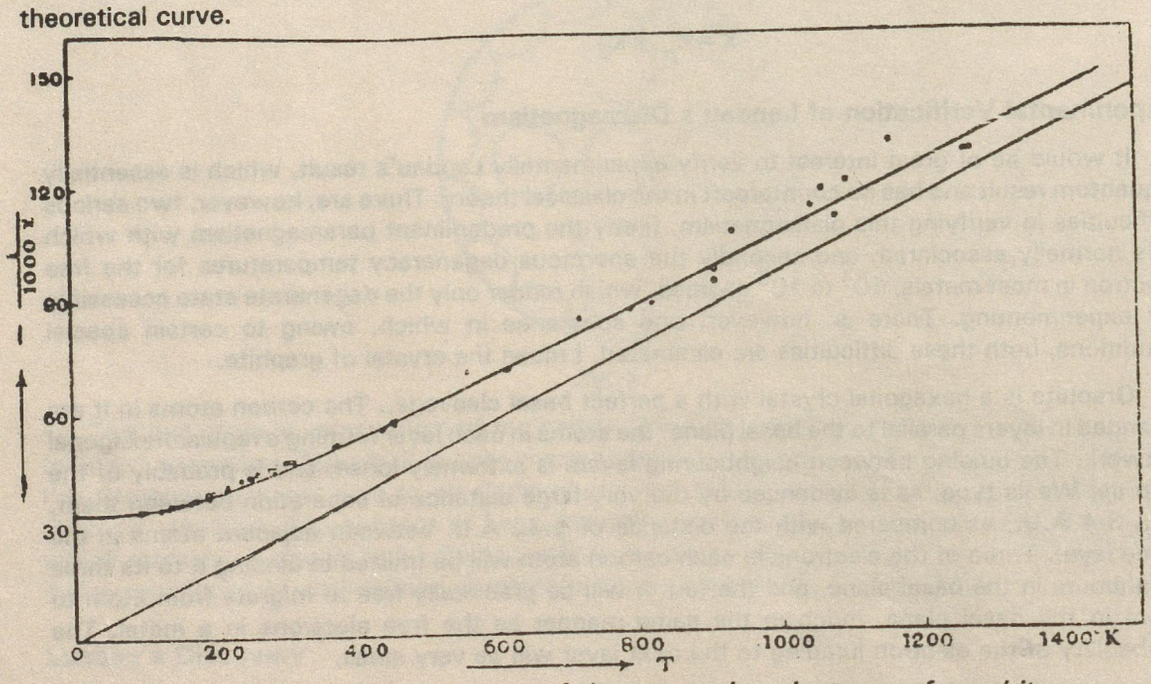


Fig. 2. Temperature variation of the magnetic anisotropy of graphite

That one electron per carbon atom should be free to move about in the basal plane agrees, as we have just seen, with the known structure of the crystal. It is further gratifying to find that there is a Brillouin zone which can just accommodate 3 electrons per carbon atom, which is a flat hexagonal prism bounded by {000.2} and {2$\bar{1}$ $\bar{1}$.0}, and the energy-discontinuities across all the faces of the zone are large. There is a bigger zone bounded by {000,2} and {2$\bar{2}$0,0} which can just contain all the 4 valency electrons, but the energy-discontinuity across {2$\bar{2}$0} is small.

The restriction of the freedom of motion of the metallic electrons in graphite to the basal plane is also evidenced by the enormously greater electrical conductivity of the crystal in the basal plane than along the normal to the plane; the ratio of the two conductivities, according to some recent measurements by Mr. Ganguli and the present writer, is larger than 10^4, probably very much larger.

The agreement between the experimental and the theoretical values plotted in Fig. 2 may be regarded as an experimental demonstration of the Landau diamagnetism of a free-electron gas, and of the temperature variation in accordance with the statistics of Fermi and Dirac.

The Mobile Electrons in Aromatic Molecules

Further, the magnetic data for graphite lend support to the view that one electron per carbon atom in the crystal is practically free to migrate from atom to atom through the whole layer. Following Lennard-Jones we shall call it the mobile electron, so as to distinguish it from the other three valency electrons in each carbon atom, which are localized and take part in binding it to its three neighbours. The occurrence of such mobile electrons is characteristic of all aromatic molecules—each layer in graphite can be regarded as a single molecule consisting of a very large number of condensed benzene rings—and is an essential feature of the quantum mechanical theories of the structures of these molecules. Their mobility is a necessary consequence of the Uncertainty Principle, according to which the larger the region assigned to these electrons, the smaller would be their kinetic energy. Any localization of these mobile electrons, such as is implied, for example, in the conventional double-bond (in which a pair of such electrons is involved), will naturally correspond to a very large kinetic energy for these electrons; it is equivalent to restricting the wave-lengths of the standing electron waves to small values of the order of the length of the double-bond, whereas if the electrons are mobile, greater wave-lengths, of the order of the dimensions of the whole molecule, will also be permitted, thus conducing to a lowering of the energy, and to a correspondingly increased stability.

This is essentially the solution offered by quantum mechanics to the old controversy regarding the locations of the extra bonds in the benzene ring, they are not located at all! If we prefer it, we may, following Pauling and Wheland, express the same results in this form: the actual structure of the benzene ring is that obtained by the 'resonance' between the following five canonical structures, the coefficients to be attached to the wave-functions representing these structures being given by

$$\psi = 0.622\,(\psi_{I} + \psi_{II}) + 0.271\,(\psi_{III} + \psi_{IV} + \psi_{V}).$$

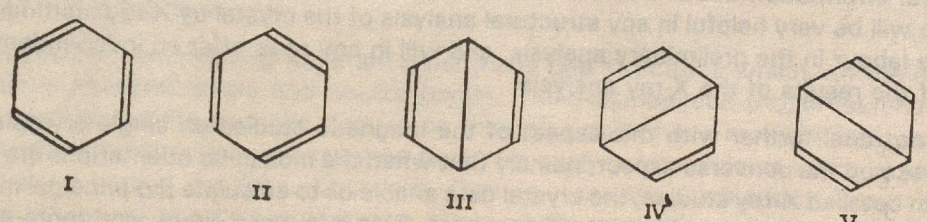


Fig. 3

The first and the second of these structures can be recognized as Kekule's and the remaining three as Dewar's. The structures proposed by Claus, Ladenburg and others, can all be obtained from the above five by suitable combinations.

The number of such canonical structures becomes very large even for the simplest of condensed ring molecules. For example for naphthalene, the number of such structures is 42, and for the three-ringed molecules anthracene and phenanthrene, the number is 429, and so on. If one has a partiality for any particular model, he can with a little diligence find his favourite in this list.

The Diamagnetism of the Mobile Electrons

One direct consequence of the freedom of the mobile electrons in benzene to migrate from atom to atom over the whole ring, would be an abnormal diamagnetism, confined to the direction perpendicular to the plane of the ring, because the diamagnetic moment is proportional to the area of the orbits described by the electrons under the influence of the magnetic field, and the mobile electrons can describe very much larger orbits in the plane of the benzene ring than the localized electrons. Those diamagnetic effects should be even more marked in plane condensed ring molecules like naphthalene, anthracene, etc., in which the migrations of the mobile electrons can be more extensive. This explains the remarkable diamagnetic anisotropy exhibited by aromatic molecules. For example in benzene, the diamagnetic susceptibility along the normal to the plane of the molecule is nearly $2^1/_2$ times that along directions in the plane. Indeed the observed large diamagnetic anisotropies of these molecules offer the most striking evidence for the presence of the mobile electrons.

When such magnetically anisotropic molecules are arranged in a regular manner as in a crystal—in most organic crystals the molecules retain their individuality—the crystal as whole will naturally exhibit an anisotropy, whose magnitude will depend on the anisotropy of the individual molecules and on their orientations relatively to one another. The closeness of approach of the molecules, which may not be the same along different directions in the crystal, will have practically no effect on the crystal anisotropy, since the diamagnetic moments induced in them will be too feeble to influence one another. In other words, the susceptibility of the crystal along any given direction will be merely the sum of the susceptibilities along this direction of all the constituent molecules.

When the magnetic constants of the molecule are already known, from measurements of the magnetic double-refraction of the substance in the liquid state or in state of solution in suitable solvents, magnetic studies on the crystal should enable us, in favourable cases, to obtain useful information about the orientations of the molecules in the crystal lattice. Such information will be very helpful in any structural analysis of the crystal by X-ray methods, since it may save labour in the preliminary analysis, and will in any case offer an independent check on some of the results of the X-ray analysis.

I shall not deal further with this aspect of the magnetic studies on single crystals, and I shall now take up the converse aspect, namely that when the molecular orientations are already known from detailed X-ray studies, the crystal data enable us to calculate the principal magnetic constants of the molecules, which interest us here. This is a more direct, and more accurate method for calculating the molecular magnetic constants, than the one based on measurements

of the magnetic double-refraction in the liquid state, and besides is more general in its applicability.

The Magnetic Anisotropies of Some Plane Aromatic Molecules

Extensive measurements have been made by Bhagavantam, Banerjee, Mrs. Lonsdale and the present writer on the magnetic properties of organic crystals, particularly of the aromatic class. For some of these crystals complete X-ray analyses have been made by Robertson and others, by the Fourier method. I give in the following Table the magnetic constants for some plane aromatic molecules, calculated from these data. K_1, K_2 and K_3 represent the three principal diamagnetic susceptibilities of the molecule, per gm. mol., and are expressed in the usual unit 10^{-6} c.g.s, e.m.u.; K_3 refers to the direction normal to the plane of the molecule; the directions of K_1 and K_2 in the plane of the molecule are as marked at the head of the Table. In those crystals in which the X-ray data are not sufficiently precise to enable us to calculate K_1 and K_2 separately, only one value is given in the Table, which will be a good approximation to either of them.

It will be seen from the Table that for all the molecules, the susceptibility along the normal to the molecular plane, namely K_3, is numerically much larger than either K_1 or K_2, in the plane, and that K_1 and K_2 are of comparable magnitudes. The difference, $\Delta K = K_3 - (K_1 + K_2)/2$, which may be taken to be the contribution from the mobile electrons, wholly directed along the K_3 axis, is given in the last column of the Table; it is roughly proportional to the number of benzene rings in the molecule.

Optical Evidence for the Mobile Electrons in Aromatic Molecules

The restriction of the freedom of migration of the mobile electrons in these molecules to the molecular plane, is also evidenced by the striking directional variations in some of the optical properties of these molecules, observed some time ago by Mr. P. K. Seshan and the present writer. Let us take for example the plane condensed ring compounds naphthacene dibenzanthracene, etc. They all have characteristic absorption and fluorescence bands in the visible region of the spectrum, which are presumably due to the transitions of the mobile electrons. It is found experimentally that it is only the component in the molecular plane of the electric vector of the incident light- wave, which is absorbed by the molecule, whereas the component along the normal to the plane is not absorbed at all. In fluorescence also it is the component of the electric vector to the molecular plane which excites fluorescence, the perpendicular component being quite inactive. An elegant quantum mechanical interpretation of these properties has recently been published by F. London.

Other Conjugated Systems

Besides the benzene ring there are other plane ring structures which, on the conventional view, have alternate single and double bonds. Their diamagnetic properties should be very similar to those of the benzene ring, since they also must have mobile electrons which can migrate all over the ring. I shall mention here two such compounds, studied recently for their magnetic properties by Mrs. Lonsdale. One is cyanuric trichloride. The two principal susceptibilities of this molecule in the plane of the cyanuric ring are —70.9 and —71.2

Molecule	$-K_1$	$-K_2$	$-K_3$	$-\Delta K = \frac{1}{2}(K_1+K_2)-K_3$
Benzene	37	37	91	54
Hexamethylbenzene	102	102	164	62
Hexaethylbenzene	165	165	231	66
Durene	82	77	144	66
Diphenyl	63		182	119
Terphenyl	97	98	271	178
Quaterphenyl	122	110	372	256
Tolane	80	67	197	123
Fluorene	73		194	121
Naphthalene	56	54	169	114
Anthracene	76	63	252	163
Phenanthrene	74		240	166
Naphthacene	93		295	202
Chrysene	88	83	311	228
Pyrene	81		303	222
1, 2; 5, 6—Dibenzanthracene	110		398	343

Table 1

respectively, whereas the third susceptibility, which is along the normal to the ring, is —101.3, which is numerically much larger. The diamagnetic contribution from the mobile electrons is thus about —40, as compared with the value —54 of the mobile electrons in the benzene ring.

The second compound is metal-free phthalocyanine. The phthalocyanines are complex organic compounds, which are related to the natural porphyrins. They have been studied extensively by Linstead and his collaborators, and they have the formula $C_{22}H_{16}N_8M$, where M is a metal atom like Ni, Cu, etc. The metal atom can be removed altogether, and the metal-free compound has the formula $C_{22}H_{18}N_8$. A complete X-ray analysis of the structure of this compound has been made recently by Robertson, and the molecule is found to have the following structure :—

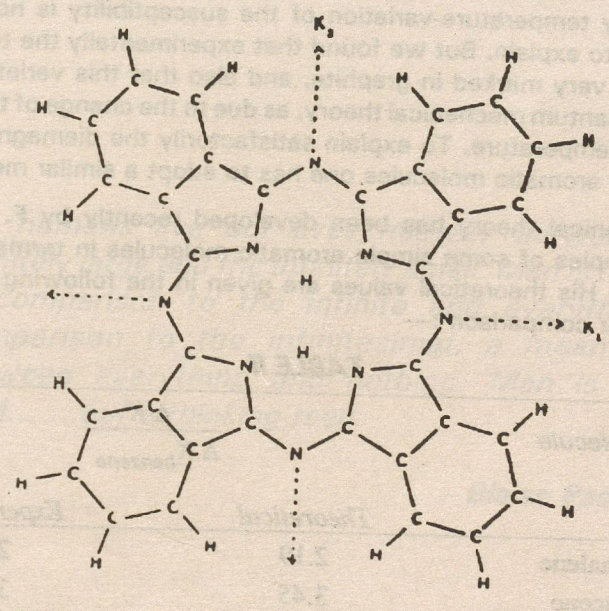


Fig. 4. Metal-free phthalocyanine molecule.

The most interesting part of this molecule, from our present point of view is the central zig-zag ring. It is a 16-membered ring of alternate carbon and nitrogen atoms, with two hydrogen atoms somewhere in the interior. This ring should exhibit resonance phenomena like the benzene and the cyanuric rings, and in view of its very large size, its diamagnetism along the normal to the plane of the ring should be enormous.

This is verified experimentally. The principal susceptibilities of the molecule are $K_1 = -120$, $K_2 = -165$, $K_3 = -982$. The susceptibility along the normal to the molecular plane is thus nearly 7 times that for directions in the plane. Even after allowing for the contributions from the outer rings, the contribution from the central 16-membered ring should be very large indeed, reminding one of the magnitudes involved in graphite.

Some Theoretical Considerations

Attempts have been made to calculate theoretically the magnitude of the diamagnetic anisotropy in some simple aromatic molecules. Adopting a semi-classical theory—which we have adopted here in our description of the diamagnetic properties of the aromatic molecules—Pauling and Mrs. Lonsdale have evaluated the effective sizes of the orbits which the mobile electrons will describe in the plane of the molecule under the influence of a magnetic field incident perpendicular to the plane, and thence have calculated the contributions which these electrons will make to the diamagnetism. The values thus obtained agree roughly with the experimental values.

On this basis, for example, the large anisotropy of graphite would be attributed to the very large size of the orbits which the mobile electrons can describe in the basal plane, in the magnetic field. On this view any temperature-variation of the susceptibility is not contemplated, and indeed will be difficult to explain. But we found that experimentally the temperature- variation of the susceptibility is very marked in graphite, and also that this variation can be explained quantitatively on the quantum mechanical theory, as due to the change of the energy distribution of the electrons with temperature. To explain satisfactorily the diamagnetic behaviour of the mobile electrons in the aromatic molecules one has to adopt a similar method.

A quantum mechanical theory has been developed recently by F. London, and he has calculated the anisotropies of some simple aromatic molecules in terms of the anisotropy of the benzene molecule. His theoretical values are given in the following Table along with the experimental values for comparison :—

TABLE II

Molecule	$\frac{\Delta K}{\Delta K_{benzene}}$	
	Theoretical	*Experimental*
Naphthalene	2.19	2.11
Anthracene	3.45	3.39
Phenanthrene	3.19	3.07
Pyrene	4.16	4.11
Diphenyl	2.21	2.20

Attention may be drawn to one or two features in the experimental values, which are not obvious on Pauling's theory, but which follow from London's calculation: the anisotropy of diphenyl is found to be considerably larger than twice that of benzene; and there is a marked difference between the anisotropies of anthracene and phenanthrene.

It is interesting that experimentally the diamagnetic susceptibilities of the mobile electrons in chrysene, pyrene, and other condensed ring compounds do show an appreciable temperature-variation. This variation, however, is much smaller than in graphite, suggesting that the kinetic energies of the mobile electrons in these should be much larger than in graphite. This is indeed to be expected.

SECTION 2

We humans live our lives midway between the infinitely large and the infinitely small. Man is nothing in comparison to the infinite and everything in comparison to the infinitesimal, a mean point between everything and nothing. Man is but a reed.....but a thinking reed.

- Blaise Pascal

- *Nobel Prize of 1998–The Fractional Quantum Hall Effect*
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- *Department of Physics and Professor K. S. Krishnan*
- *Promoting Physics research in Indian Universities*
- *Scientific Research in Indian Universities – missing feedback loops*

Noble Prize of 1998
The Fractional Quantum Hall Effect

B. K. Agrawal

Recently the Swedish Academy conferring the Noble Prizes have announced the names of the winners of Noble Prizes of 1998 in different disciplines. In physics, three American physicists, Drs. Robert B. Laughlin, Horst L. Stormer and Daniel C. Taui have been awarded the Noble Prize for their discovery of a new form of quantum fluid with fractionally charged excitations.

One of the manifestations of these excitations in experiments is the Fractional Quantum Hall Effect. In fact, the Fractional Quantum Hall effect was first discovered by Tsui and Stormer in their experiments in 1982. Dr. R. B. Laughlin explained their results the following year.

Earlier, the Integral Quantum Hall Effect was discovered by K. v. Klitzing in 1980 who found that the Hall effect in silicon does not behave in a linear fashion but instead creates 'Steps' along the strength of the magnetic field. van Kilitzing won the Noble Prize for this discovery in 1985.

Dr. Robert B. Laughlin is professor in physics in Stanford University. Dr. Laughlin was born in 1950. He completed his Ph.D. in 1979 from MIT. Dr. Laughlin is a condensed matter theorist and his current research interest is primarily high temperature superconductivity theory.

Dr. Horst L. Stormer was born in Frankfurt in 1949 and got his Ph.D. degree in 1977 at Stuttgart University. At present he is associated with Columbia University and Bell laboratories. Dr. Stormer's interests are quantum confined systems.

Dr. Daniel C. Tsui was born in 1939 in China. He received his Ph.D. degree in 1967 at University of Chicago. He is associated with Department of Electrical Engineering at Princeton University. His recent interests are, Quantum Hall Effect, quantum well infrared detectors, two-dimensional electron systems.

The Fractional Quantum Hall effect (FQHE) is a fascinating manifestation of simple collective behaviour in a two-dimensional system of strongly interacting electrons. At particular magnetic fields, the electron gas condenses into a remarkable state with liquid-like properties. This state is very delicate, requiring high quality material with a low carrier concentration, and extremely low temperatures. As in the integer *Quantum Hall Effect*, a series of plateaux form in the Hall resistance. Each particular value of magnetic field corresponds to a filling factor (the ratio of electrons to magnetic flux quanta) nu = p/q, where p and q are integers with no common factors). q always turns out to be an odd number. The principal series of such fractions are 1/3, 2/5, 3/7 etc., and 2/3/3/5, 4/7, etc.

There are two main theories of the FQHE :

* **Fractionally-charged quasiparticles.** This theory, proposed by Laughlin, hides the interactions by constructing a set of quasiparticles with charge $e^* = e/q$, where the fraction is p/q as above.

* **Composite Fermions.** This theory was proposed by Jain, and Halperin, Lee and Read. In order to hide the interactions, it attaches two (or, in general, an even number) flux quanta *h/e* to each electron, forming integer-charged quasiparticles called Composite Fermions. The fractional states are mapped to the Integer QHE. This makes electrons at a filling factor 1/3, for example, behave in the same way as at filing factor 1. A remarkable result is that filling factor 1/2 corresponds to zero magnetic field. Experiments support this.

Tsui and Stormer, then at Bell Laboratories in Murray Hall, New Jersey, performed experiments on the Quantum Hall Effect in the semiconductor gallium arsenide using even lower temperatures and more powerful magnetic fields. To do so, they created a unique environment, a trap in which to restrain electrons on a two- dimensional plane. This was done by sandwiching two dissimilar semiconductor wafers—gallium arsenide on one side and gallium aluminum arsenide on the other. Electrons accumulated at the interface between the two semiconductors and were tightly confined. Next, the, researchers cooled the electron trap down to a tenth of a degree above absolute zero.

To their surprise, Tsui and Stormer found that the next step in the Hall resistance was three times higher than von Klitzing's highest recorded step. Later, Tsui and Stormer found more steps, which initially could not be explained. The heights of the new steps could be expressed with the same constant used in earlier work, but were now divided by different fractions—thus, the term *fractional quantum Hall effect.* This would be impossible, since electrons cannot have fractional charges. Laughlin later determined that the magnetic field had created "holes" in the two-dimensional sheet of electrons. Called vortices, these were similar to a whirlpool in a lake, in the absence of water, the vortices represent an absence of charge.

Quantum sheets in high magnetic fields show a resistance that is quantized to a few parts in 10^8. This is known as the Integral Quantum Hall Effect. Yet more unusual things happen in the highest-quality samples. Novel electron quantum-fluids form, which exhibit fractional quantum numbers (such as 3/7, 5/11...) and they harbor objects that carry an exact fraction of an electron charge, e.g. 1/3 e. Furthermore, the magnetic field seems to transform fermions into bosons and vice-versa. These class of phenomena is known as the Fractional Quantum Hall Effect which was discovered some 15 years ago but keeps surprising us with new revelations. Transport in quantum-wires is also full of surprises. Again, the resistance is quantized and electron motion is more appropriately described in terms of a many-particle waves than in terms of individual electron. In quantum-dots one can achieve the controlled addition and subtraction of individual electrons.

The interaction of many electrons rather than the property of any individual particle is at the origin of all such observation. The associated theory is challenging and at the forefront of today's efforts to understand complex many-particle systems.

The discovery of apparently fractional electron charge has opened a new era and has had impact on many branches of physics. Researchers around the world continue to make new discoveries that spring from the fractional quantum Hall effect.

Development of Scientific Research in India—A Casualty

Krishnaji[1]

One cannot begin writing about scientific development in India without paying the highest tribute to the unique and imaginative personality of our popular Prime Minister Shri Jawahar Lal Nehru. His enthusiasm for and his encouragement to scientific research in this country have been, if I may say so, many times more than that of the scientists themselves. It is not difficult to imagine how different the state of affairs would have been if the scientists or planners of scientific research in India had shown greater imagination and made better use of the encouragement given by the authorities who have been anxious to do their best.

Unhappy State of Affairs

In the face of an apparently overwhelming evidence in the shape of a large number of National Laboratories, research institutes, new universities, Vigyan Mandirs and a number of development councils and committees, it is difficult to convince anybody in India that we have not progressed much in the field of scientific research. On the other hand, it is equally difficult to convince anybody outside India as well as a large number of young scientists in India that we have made any worthwhile progress in this sphere. It can be said, that one must 'learn to walk before running' and, this takes time and therefore one should not mind the effort and time if one is learning to walk properly. Unfortunately, however, many are doubtful even about the soundness of the principles on which our planning is based. One must discriminate clearly between the technological developments made possible through loans and aids (technical and financial) from other countries, and the development of scientific research which will lay the foundations of future industrial, technological and scientific developments made and sustained by our own people without external help. A practical measure of the success of planning in this direction, to my mind, should be the ratio of the volume of research and trained research personnel produced to the amount of money spent on it. It appears, however, that this ratio for India at present, will be found among the lowest in the world. It is unfortunate that scientists as well give a false picture of the state of development and thus make people complacent and proud of something which does not exist. The institution of Indian Science Congress as it is run at present leaves much to be desired. It is growing up as a scientific counterpart of the annual gathering of social and political organizations.

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1. Former Professor of Physics, University of Allahabad, Published in Science and Culture, Vol. 27, 128, March 1961.

Some of the Paradoxes

It is not uncommon to find Directors of laboratories or Vice-Chancellors of universities complaining that they are not finding suitably qualified scientists to fill up a number of vacancies (specially in physics and engineering) in their organization and at the same time one often comes across highly qualified young scientists not getting suitable jobs where they can do some useful work. We are told that India is a poor country and can not afford to spend sufficient money on research and yet it is not rare to find specialized laboratories for almost identical subjects being started by different departments of the Government. At times, two different sections of the same laboratory may be seen handling similar projects and even two officers of the same section handling similar projects separately. Big laboratories may be found stuffed with costly equipments purchased from abroad but with practically nobody to use them and at the same time competent and qualified men sitting in rooms with inadequate equipments to do some useful work. Younger scientists are told that they should not go abroad and stay in foreign countries for learning research because there are enough facilities available in India and the motherland needs their services badly. When these young men, however, are interviewed for employment, they are invariably asked. 'Have you worked in a foreign country'? or 'How long have you been in the States ?' The young men to their surprise find that their services are really not needed unless they can overawe the experts by the foreign acquired mannerism and confuse them with names of powerful tools of experimental and theoretical research. Such is the paradox in which we find ourselves to day.

Heavy Work for the Top Scientists

The number of top ranking scientists in the country are few but the number of assignments needing their services as experts are far too many with the result that one man has to attend far too many appointments and responsibilities. The selected few, who proudly possess science in India, are required to attend all sorts of conferences in other countries and may be in connexion with subjects they may not be interested in. The load of work goes on increasing since they cannot (or do not want to) find their understudies to relieve them partly of their responsibilities. They probably derive moral support from the fact that even Nehru has not been able to find his substitute. It appears that some of them may not like to help create their successors. The administrative responsibilities at times make their professional work as of secondary importance. It is not understood why they do not realize that when we neglect our profession we also become unfit as competent technical advisers.

Universities : Best Places for Research

Everybody will agree that universities are the best places for research activities. The climate of research and original thinking can never develop in a Government establishment whether it is under SRCA Ministry. Defence Ministry, Communication Ministry or Home Ministry. The reasons are very obvious and simple. The future of the worker in a Government laboratory depends upon the progress report and the confidential report submitted by his officer and this fear is enough to kill initiative and independent thinking. This may not be true in all cases, but I so feel that this is the case with the majority of workers in the Government establishments. Very senior officers like Assistant Directors or Principal Scientific Officers have been heard to say that if a particular idea is not liked by the chief it should not be discussed. The creative

research cannot develop except in a free and unfettered atmosphere; freedom and criticism both are shy of 'officers' and the Government organization can not work without officers. Apart from the greater degree of independence of thought, action, and expression in the universities, one is likely to get a team of enthusiastic and willing workers more easily there than in Government establishments. The possibility of getting a research degree, of publishing the results quickly in a research journal and thus getting due credit for the work done, and the possibility of commanding spontaneous respect and reputation among a large number of students are some of the very powerful incentives for research in the universities. These factors are lacking in Government organizations. Instances are not infrequent of individuals who produced very good work when they were in the universities but almost stopped producing any work even in a decade or so after joining a Government establishment. Some of the research workers in Government organizations seem to translate the 'Parkinson's law or the pursuit of progress' in practice. People sometimes begin to doubt whether it is really true that universities are the best places for research activities in India because they argue in such a case people like Bhaba, Krishnan and Mahalanobis etc. should have been in the universities. It is, really, the biggest misfortune of this country that our top scientists are heading Government establishments and not university research centres. A situation, in which scientists prefer to remain directors instead of professors, has to be taken note of, rather, seriously. If this is the result of our planning, I must confess we have planned not for progress but for neglect of the progress of scientific research in our country. It will be difficult to find a parallel in any of the advanced democratic countries in the world.

Unfair Treatment to Universities

One may be pardoned if he is inclined to believe that the absence (total or partial) of the few topmost scientists from the universities is responsible for the step-motherly treatment given to them as compared to CSIR laboratories, Defence Science Units and Indian Institutes of Technology. A senior scientific officer Grade-I in any one of the Government establishments and an Assistant Professor in any Indian Institute of Technology enjoys almost the same emoluments as that of a University Professor. An Assistant Director of CSIR laboratory, a Principal Scientific Officer in Defence Science Service or a Professor of Indian Institute of Technology draws a higher salary than that of a University Professor. I do not know how the top scientists, particularly those who have something to do with universities as well, tolerate or acquiesce in such a state of affairs. It is a fact that except for the universities of Delhi and Calcutta, other universities have only one professor in each department whereas National Physical Laboratory alone has about eight Assistant Directors and twelve Senior Scientific Officers of Grade-I. Does it mean that the controllers of scientific research in India do not want research to be done in the universities or do they think that a research worker in the universities has any less material need than in a Government research laboratory ? It is true that a number of university teachers remain content with lower salaries because they realize that freedom of thought and action involve sacrifice. Even they get disgusted when they find that politicians in power and officials even indulge in unfair criticisms when they have produced more research for the money spent on them and have in addition trained research personnel for the country. A university man feels discouraged to find that his counterpart is looked after in a better way for a poor performance. The result of this apathy towards university research worker is that

competent and qualified young men, who cannot stand these disabilities, are leaving the universities for better jobs elsewhere, and are normally lost in the field of administration.

University Authorities May Not Often Encourage Research

All is not well in the universities also. The torch bearers of academic standards themselves do many things which discourage research. Original thinking and translating it into action requires a certain amount of time in which one should not be hustled or disturbed. The age old syllabus and its teaching by the age old methods takes enormous amount of one's time without making the student any wiser. The equitable distribution of work load (teaching) does not permit anybody who is conducting research to transfer some of his teaching load to colleagues not interested in research. Well, you are paid for teaching and not research ? It is intriguing to observe that every work in the university other than research is paid for. For example, one is paid for teaching, for maintaining discipline as a proctor, for invigilating during examination, for examining answer papers, for working as a tabulator, for coaching hostel students or scheduled caste students, for officering the NCC cadets, for looking after the students as a hostel superintendent etc. If one happens to be interested in research activity, he has to subscribe to journals, pay for the price of reprints out of his own pocket. Curiously enough the audit rules do not permit of expenses on correspondence connected with research. Besides, the library can not subscribe to all journals.

I have failed to understand how anybody who is not actively engaged in research can possibly teach and guide effectively post graduate students; but this is what takes place on a very large scale in most of the university departments. In most of the university science faculty departments there is a restriction on the number of research scholars one can supervise either by convention or by rules. It is an established fact today that scientific research worth the name is not possible by restricting oneself to narrow classification of subjects like physics, mathematics, chemistry, zoology or botany etc. The various subjects overlap so much that a physicist may specialize in something which is in the domain of the chemists or the biologists. A mathematician may enter the field of the physicists or linguistics and so on. The universities do not easily permit a member of the physics department to carry on his research work in the zoology department or a member of the mathematics department to do so in the physics department on the hardly justifiable plea that it creates a lot of complications if such relaxations are made. A top scientist who has control over the universities, as well as Government department, told in my presence a young friend who is a member of the mathematics department and has taken his Ph.D. in theoretical physics, that it will be difficult for him to get a job in the physics department of a university because his basic degree is in mathematics. The young theoretical physicist was evidently disappointed. I do not mean that this is always done. I have mentioned this incident to show that our top scientific persons hold such opinions and naturally control things in the same manner. A very serious matter which requires attention is the way in which active research workers have to move from one place to another. A certain Assistant Professor works hard and does creditable research, say, in University-X, and receives a sizable grant worth several lakhs of rupees for purchasing equipments; he builds up an excellent laboratory after spending some years of his active life and several lakhs of rupees. Soon after this, he is appointed as a Professor in the University-Y, where he has to start all over again and spend some more years of his active life and more money. The laboratory-X in

the meanwhile lies useless in most cases for all times to come. It may be interesting to note that the Y-University professorship fell vacant because the Professor there was appointed at Z-University and he left his active laboratory which he had built according to the requirements of his subject, owing to differences in superannuation rules. It is not understood why a person who can be regarded fit as a Professor in one university can not be allowed to stay as professor in the other universities where he built a laboratory and was actively carrying on research. This is all the more puzzling when the experts who do the job of selecting professors are very few and happen to be common factors in both the universities. Further, it is the same Government which finances the two places in question. Cases of the type quoted above are occurring so frequently that one feels surprised why nothing is done to stop this waste of time and money, both of which we need so badly. The research output as a result of all these anomalies is the natural casualty.

In some universities including the one to which I belong, a very curious situation exists as far as recognition of work and merit in terms of emoluments is concerned. If you go to some foreign country for conducting higher studies and advanced research and remain on leave without pay (in most cases) for some years, after your return you get a salary lesser than what you would have got if you did not go on leave and did not do creditable research. Some authorities argue that increasing qualifications is one's personal benefit and so why should the university pay for it. But in case you are not a university employee, you may be appointed with a higher starting salary because they think that the university will benefit by your qualifications and experiences and therefore should pay for it.

The Tyranny of Red Tape

When everything else is all right, it is the red tape which may often cause a disaster and make completely ineffective many of the good schemes launched after long deliberations. The red tape is held responsible for the sad death of Dr. Joseph and probably of many others not generally known. The red tape is troublesome anywhere and more so in the field of scientific activity because research scientists are said to be allergic to it. I know the cases of a few brilliant and mature Indian scientists who have left India and are working in the United States because they were harassed by the red tape.

One of the typical examples of the all pervading red tape in action, is seen when you want to get some equipment from outside India. Before you can get the desired equipment you have to get three quotations, a proforma invoice, import license, no manufacture certificate, duty concession certificate and the necessary funds. All these items have to be procured from different agencies through proper channel and very often these are not easily available or else reach you after a very long time and in the meanwhile the price of the equipment has changed and you have to proceed all over again as far as proforma invoice, allocation of funds and import licence are concerned. Purchase through UNESCO coupons does simplify the procedure but only as far as import licence is concerned. Sometimes the equipment reaches India from the foreign country in a reasonably short time, say, two months but invariably it takes anywhere between four to eight months before it can be cleared through customs and reach you. In a large number of cases, the problem you had in mind when the equipment was ordered, has been already solved in some other country. I am sure things can be simplified with a little thoughtful effort in this direction. I do not need to elaborate on this point because this is known

to everybody but they are unable to get over the difficulty. The red tape has converted every able Indian scientist into an administrator.

Anybody who tries to raise his voice against the conventional methods is immediately overawed by the mention of a galaxy of renowned Indian scientists such as Ramanujam, Ray, Saha, Raman, Bhabha, Bose, Krishnan, Kothari etc. who. they say, are products of these very methods of education, research and administration. The wise men have however, said 'genius is not a product of any system but is produced inspite of the system!' The success of a system is not to be judged by the five per cent extra brilliant people whose brilliance could not have been reduced by anything or by the another five per cent whose dullness could not have been brightened by the best system, but by the bulk of ninety percent people who are susceptible to the climate all around them and are capable of being moulded.

What Are We to Do

It is my conviction that universities are the best places where high quality research can be produced in shorter time and at much lesser cost than any other establishment. I do not mean that research establishments run by CSIR, Defence Science, and other Ministries, are not necessary. Those establishments have to be there but they should normally take up applied research and undertake certain specialized types of work.

Uniformity of Emoluments

The research output (quality and quantity both) from the universities in the present context of things, will never increase as long as such a large disparity in emoluments exists and as long as facilities are provided for earning extra money by doing all kinds of extra unacademic work. The only solution of the problem is to raise the emoluments of the university teachers to a decent level which is comparable to those of other research establishments so that they do not need to run after extra work for augmenting their income. When this has been done, all the extra payments can be stopped and the extra work distributed equitably as part of normal duties. A department may have on the permanent staff 30% of the total strength as professors and 50% as assistant professors and 20% as fellows. The scales of salaries may be: professors—Rs. 1000-1800, assistant professors—Rs. 400-1100 and fellows—Rs. 250-450. The fellows will normally be required to run practical classes only and devote half the time to research. The research fellowships financed by CSIR and UGC will continue to be there.

Radical Change in Syllabus, Teaching and Examination Methods

Increase in emoluments alone will not work as a magic wand and produce good research and competent research personnel unless drastic changes are made in syllabus, teaching methods and the examination system.

If one looks into the problem a little more closely it will be clear that at present it is the examination system which dictates the syllabus, which in turn controls the teaching methods. In the scheme of things, the examination thus controls our education and becomes most important when it really should be the least important item. The system of external examiners compels everybody to finish the course in such a manner that the students might be able to answer the stock questions. As a natural corollary to this, memory is at a premium and

intelligence is at discount. The method is designed to iron out independence of mind, originality, and native curiosity, and to turn intelligent young men and women into automatic machines. An examination is a very necessary thing, and when properly devised it measures the intellectual development of the student as a result of the educational experience he has undergone. Our present examinations are very unreliable and inaccurate from this point of view. Nor are they efficient ways of producing graduates, which is evident from the fantastic failure rates, at the various examinations. Once we are able to shake off the control of examination on us, it will be possible to achieve the correct objective of lecturing to a class. The present teaching method upholds the definition of Education given by some one as 'Education is that mysterious process whereby information passes from the lecture notes of the professor through the fountain pen on to the note book of the student, without passing through the minds of either'. The main object of a lecture should be to stimulate the student's mind, to get him to think, to suggest new ways of looking at subjects to open a window so that the student sees his subject in a wider perspective. The primary appeal of the lecturer must be to the students' mind, not to his memory. They have to be taught the art of studying, of reading, of using a library, of digging out information by their own efforts. We should hold discussions, seminars, let the students write essays and read papers, require them to solve original problems which are not in the book. Education rightly understood is not to 'put in' but to 'draw out'. It is in this way that education becomes a training, a discipline in tackling problems with intelligence, resourcefulness, and creative freshness. It should be clear that education comes through doing, not through listening. The above objective can be realized only if the system of external examiners is given up. The person who teaches a certain branch of subject should be responsible for examining the students in that branch and grading them. This will automatically put a stop to hankering after a number of examinerships for earning more money. I have devoted a little time to this problem because a proper solution to this will enable us to produce intelligent personnel who would be suited very much better for quality research as well as any work in life. We can then raise the standard of our research degrees as well by introducing more stringent conditions with regard to knowledge, understanding and originality.

Under the present circumstances of our slender resources, financial and otherwise, it is very necessary that duplication of effort has to be avoided as far as possible. This is necessary only till the time our resources become adequate. This work can be done admirably by most of the Government agencies.

Instruments Industry Should be Given High Priority

Instruments of some kind or the other are needed by all kinds of research including theoretical physics and mathematics (they need calculators and computers). One can easily see that it is futile to depend on the instruments imported from other countries because they cannot serve our purpose for all times. It takes very long to get them and usually they are obsolete by the time they are here. In some cases they do not stand the rigours of our climatic conditions. They can not be maintained in operating conditions after a few years because spares are not available. Well, the most important point is that you always work with a comparatively obsolete type of instrument. The import of costly, complicated and automatic machinery lands us into another amusing situation; we have to choose problems to the convenience of these machines and only routine problems will submit to such a treatment! One of the Government

organizations which is supposed to carry out high priority top secret work for the country has been solving the problems till lately in a very simple way. They decided not to import any new equipment but to carry on their research with the surplus war disposal instruments most of which turned out to be unserviceable.

Our industrialists normally will not undertake a venture of making instruments which may be used in very small numbers; the only place where instruments can be used in large numbers is the industries themselves, and this forms a vicious circle. This is another direction where the Government agencies could and should have come to our help. I think a very large part of the National Physical Laboratory, the Central Electronics Engineering Research Institute should have engaged themselves in designing and making on small scale, high quality instruments needed for research. I mention NPL and CEERI only, because most of the instruments used today are either optical or electronic.

We must therefore stop depending on imported instruments and start developing our instruments in right earnest. We must create an awareness in the industries regarding the benefits of using and making instruments; in the meanwhile the Government organizations should take up the work seriously.

One sometimes really wonders how small countries like Japan and Western Germany which were completely devastated during the last war and whose brilliant men were taken away to either U.S.A. or Soviet Union, have within a short interval risen up in the field of research so well. (In technology they are competing with U.S.A. and USSR in many fields). The theoretical Physics School of Japan led by Yukawa and the group at Gottingen, Germany, to mention a few examples, enjoy the highest international reputation. The fact that Indians do not lack intelligence or stamina for sustained work, has been proved beyond doubt. One only fails to understand why Chandrasekhar, Harish Chandra, Salam, Bose, Sidhu, Gupta and Khurana to mention just a few names are not leading active schools of research in India. I do not think it is the American or English money only, which is keeping them there. Even if it was so, it would have been better for us, to pay them well and let them create schools of active research in India which may breed not only high quality research but properly trained research personnel, rather than spend crores of rupees in building a large number of palatial buildings where half the money goes into the pockets of clever contractors and their supervisors.

I have not expressed these thoughts, from the narrow nationalistic viewpoint but have done so in true international sense. It is obvious that if the world has to progress, every part of the world must progress equally. Any part of the body, however small and insignificant, cannot be left in a diseased state, otherwise the body will look deformed though it may be developed otherwise. I have tried to make an honest diagnosis of the internal diseases which are eating into the vitals of scientific research in India. I hope people will realize that the multipurpose food in the shape of crores of rupees cannot be digested by the diseased body of scientific research development unless steps are taken to cure the diseases.

Physics Department and Prof. K. S. Krishnan : Some Little Known Facts

Indra Mohan Lal Das

The Department of Physics has already completed 75th years of its existence in 1997 and hence the Platinum Jubilee Celebrations. It is a momentous occasion—an occasion of deep introspection. It is an opportunity to take stock of our failures and successes. Failures must not arrest our steps on the path of development and progress and successes must not make us arrogant so as to lose the sight of emerging frontiers of knowledge. We must learn lessons from our historical past. The present endeavour is an attempt to make ourselves (specially the younger generation) aware of the long legacy or heritage of excellence for which this department was known throughout the world. Very little is known about the Physics education at Allahabad University before 1922, circumstances leading to Saha's resignation, Schroedinger's willingness to join Physics chair but his inability due to Word War II and finally Krishnan's joining of this Department. An honest attempt has been made to present an authentic history of the Department tracing its origin in the Muir Central College, its germination in the University of Allahabad and finally its full blossoming under the guidance of persons of eminence like Saha, Krishnan, Bhargava and host of others.

1. The Origin : The Muir Central College

The scheme to establish a Central College at Allahabad eventually to develop into a University was suggested in the *Public Darbar* of 1868. In the subsequent *Darbar* held on May 24, 1869 at Allahabad, Sir William Muir, the then Lieutenant-Governor emphasised the special need of a College and University at Allahabad. The Central College was established at Allahabad and it commenced work on July, 1872 in the Lowther Castle (now Darbhanga Castle) initially leased for 3 years with following staff :

1. Mr. Augustus Harrison, B.A.— Principal (taught English and Mathematics)
2. Mr. W. H. Wright, B.A.—Professor of English Literature.
3. Mr. J. Elliot, B.A.—Professor of Mathematics.
4. Maulvi Zakaullah—Professor of Vernacular Literature and Science.
5. Pandit Aditya Ram Bhattacharya, M.A.—Professor of Sanskrit.

Foundation stone of the present building was laid on December 9, 1873 by Lord Northbrook, the then Viceroy and Governor-General of India. It was designed by Mr. W. Emerson in a modified Saracenic style. Permission was also obtained to name the College after him in recognition of his firm, earnest and statesman-like trust placed by him in the sure and certain progress and spread of higher education in this part of India, in particular in establishing the Central College at Allahabad. The Muir Central College building was formally opened on April 8, 1886 by Lord Dufferin, the then Viceroy.

2. University of Allahabad : Faculty of Science

When University of Allahabad was established on September 23, 1887 as an affiliating and examining body, the Muir Central College became its nucleus and headquarters and its meetings were held here either in the library room or the Vizianagram Hall.

Mathematics in those days included Algebra, Trigonometry, Statics, Dynamics and Astronomy. Mr. Elliot took keen interest in promoting Astronomy. He donated a telescope to the college and the students used to perform practical works with telescope under the guidance of Mr. Ram Nath Chatterjee, Asst. Professor of Mathematics. Mr. Elliot was succeeded by Mr. W. N. Boutflower as Professor of Mathematics. He was also a distinguished scholar of Physics. In 1873 Mr. S. A. Hill joined as Professor of Physical Science teaching Physics and Chemistry. He died in 1890 and a memorial prize for research in science was founded by his pupils and friends in his memory. For some time Abhay Charan Sanyal officiated for him and finally Mr. J. Murray succeeded him. In 1885 a special grant of Rs. 2,300 was made for the construction of Physical Science Class Rooms. During the first 5 years the total number of Science students was 112. However, soon the number increased sharply. So in order to guaranteeing a minimum standard for Science education, J. Murray Sub-Committee in 1901 laid down the following conditions.

(i) *Teaching Staff :* One person to be appointed for each 16 students to teach practical work in Physics and Chemistry.

(ii) *Accommodation : Separate practical rooms must be provided for Physics and Chemistry.*

(iii) *Apparatus :* Up-to-date apparatus must be provided both for Lecture demonstration and practical work of Physics and Chemistry.

The Principal's Report for the year 1895-96 observes—"I need not dwell here on the necessity of an extention of the college building in order to provide new rooms for practical work in Physics and Chemistry." Efforts were also taken to concentrate to some extent on the teaching of higher branches of science. Consequently, an independent post of Professor of Chemistry was created and Mr. E. G. Hill joined the same on December 26, 1895.

In 1896, the University created a Faculty of Science and affiliation upto M.Sc. and D.Sc. was granted in 1896 and 1897 respectively. The Muir Central College was strongly organised on science side since its inception. Of five Professors listed earlier, three taught science. The subjects taught were as given below :

B.Sc. Courses : One of the following groups of subjects :

(i) Physics, Chemistry and Mathematics

(ii) Physics, Chemistry and Natural Sciences

M.Sc. Courses : Any one of the subjects in B.Sc. Course

D.Sc. : Degree can be awarded to Masters of Science after some years spent in original investigation.

During 1897-98, a Laboratory Assistant the Professor of Chemistry was appointed. The College Workshop was very useful to Science teaching, as it saved money on larger apparatus, supplied small articles at nominal cost and repaired broken instruments which otherwise would

have been thrown aside as useless.

By 1901-02, a Demonstratorship in Chemistry was created. New Science Class Rooms and Laboratories were completed. The Laboratories equipped with new fittings and apparatus was classified as one of the finest and most complete in the East.

Mr. J. Patterson joined as the first Professor of Physics during the session 1902-03. The building for the Workshop and Engine Room of the Physics Laboratory was almost complete by the end of session 1903-04. When Mr. Patterson was transferred to the Meteorological Department, Mr. J. J. Durack, M.A. succeeded him. During 1906-07, Mr. Anukul Chandra Das, M.A. was the Junior Professor of Physics. In 1907-08 Babu Sohan Lal Srivastava, M.A. was appointed Junior Professor of Physics. In the year 1910 one more Professor of Physics, Mr. Devendra Nath Pal, M.A. and a Laboratory Demonstrator in Physics, Mr. Shiva Das Mukherjee, B.A. were added. During 1911-12 another Laboratory Demonstrator in Physics, Mr. Saligram Tandon, M.Sc. was added and expenditure was incurred on the erection of additional Gasometer and Gas Plant for Physics Laboratory. In 1913 Mr. Saligram Bhargava has been shown as Laboratory Demonstrator in the University Calendar of that year. It is not clear whether Mr. Saligram Tandon and Mr. Saligram Bhargava is the same person and 'Tandon' inadvertently printed. But Bhargawa remained Demonstrator until he was appointed Professor in 1915. [He retired from the University as Professor and Head of the Physics Department in 1949].

On December 22, 1916 Mahatma Gandhi, Father of the Nation delivered a Lecture on "Does economic progress clash with spiritual progress ?" on the invitation of Economics Society in the Large Lecture Theatre of Physics (now Room No. 18)

Mr. Durack assumed the charge of Principalship on February 12, 1920. Names of other Professors of Physics at Muir Central College are : Mr. W. G. P. Wal, Mr. Chunni Lal Sahny, Dr. Wali Mohammad and Mr. Jagat Behari Seth etc.

3. Department of Physics

The Allahabad University Reorganization Act of 1921, transformed the University from an affiliating and examining body into a teaching and residential University. The reorganised unitary Allahabad University in 1922 started with the Muir Central College converted into the science block of the University. Departments of Physics, Mathematics, Chemistry, Botany and Zoology were established to constitute the Faculty of Science. The Department of Physics was sanctioned 1 Professor, 1 Reader, 2 Lecturers and 2 or more Demonstrators as required by University Regulations. The existing Laboratories were extended and new Laboratories constructed during 1922-23 at the cost of Rs. 29,702.[2] There were about 120 B.Sc. and 20 M.Sc. students. When Saha joined Allahabad University on September 17, 1923 as the First Professor and Head of the Physics Department, the Laboratories were well stocked with demonstration and class room apparatus suitable for undergraduate classes but ill equipped for M.Sc. teaching and research. But, soon Saha's love and labour bore fruit and the Department became famous world wide for its pioneering research work on spectroscopic analysis of Atomic Spectra, Ionospheric Studies, Acoustic and Ultrasonic Measurements, X-ray Spectroscopy. Nobel Laureates Compton, Sommerfeld, Eddington, Raman were some of the distinguished visitors to the Department during its heyday. Details (which can be found elsewhere.[3]) are omitted to avoid repetition.

4. Saha Awarded Carnegie Trust Fellowship

In 1935 Carnegie Trust of the British Empire selected Prof. Saha for an Overseas Carnegie Fund Research Fellowship. So, he applied for 8 month's leave out of India from the 12th October, 1935. His application was placed before the Executive Council in its meeting on August 3, 1935 but consideration of the matter was postponed [4]. However, the Executive Council in its meeting held on 19th September, 1935 resolved to grant the leave in accordance with the rules[5]. But, he could not avail the leave in the absence of any alternative arrangement of teaching during his absence. Finally, the Executive Council in its meeting on February 1, 1936 approved the following arrangements to be made during his absence on leave[6] :

(i) that Mr. Saligram Bhargava, Reader, be appointed to officiate as Professor vice Dr. M. N. Saha;

(ii) that Dr. R. N. Ghosh, Lecturer, be appointed to officiate as Reader vice Mr. Saligram Bhargava;

(iii) that Mr. B. C. Das, Lecturer, B-Grade, be appointed to officiate as Lecturer, A-Grade vice Dr. R. N. Ghosh;

(iv) that the usual allowance be granted in each case.

It was also resolved that a temporary Lecturer, B Grade, be appointed in the Department on Rs. 125 p.m. from July next (beginning of the new session).

This enabled him to go abroad and he left for Europe on 5th March, 1936[7] and subsequently, Mr. J. B. Mukherjee was temporarily appointed Lecturer, B-Grade.

Saha made an extensive tour of Europe and America and visited many laboratories and research institutes. He represented Allahabad University in the

(i) Centenary Celebrations of the University of London held at London from 29th June to 3rd July 1936;

(ii) Quinquennial Congress of the Universities of the British Empire organized by the Universities Bureau of the British Empire, London at Cambridge from 13th to 17th July 1936;

(iii) 7th World Conference of the New Education Fellowship, London held at Cheltenham from 21st July to 14th August 1936;

(iv) Concluding ceremonies of the Tercentenary Celebrations of Harvard University held on September 16 to 18, 1936.

He also delivered lectures at the Harvard College Observatory, Harvard Tercentenary and Mount Wilson Solar Observatory.

5. Saha's Resignation and Schroedinger's Appointment

Saha returned to Allahabad either by the end of 1936 or the beginning of 1937 probably wanting to return to a more active scientific life at Calcutta. The much awaited opportunity came his ways in 1938 when Dr. D. M. Bose relinquished the Charge of Palit Professor of Physics of Calcutta University to become Director of the Bose Institute following the death of Prof. J. C. Bose in November, 1937. Palit Professorship was offered to Saha which he readily accepted.

Initially, Saha applied for two years' leave without pay with effect from 20th July 1938 to enable him to accept the Palit Chair of Physics. The Executive Council in its meeting held on 13th April, 1938 was informed by the Vice-Chancellor in this connection that Dr. Saha had authorised him to state that for the present he may be granted only one year's leave. So, the Executive Council granted him one year's leave and it also resolved, that for the present the post of Professor of Physics be filled departmentally i.e., the reader should officiate as Professor and the Seniormost Lecturer, A-Grade should officiate as Reader and the Seniormost Lecturer, B-Grade should officiate as Lecturer, A-Grade and they be given usual allowance. That the post of Junior Lecturer, B-Grade be advertised[8]. Consequently, Dr. A. N. Tandon was appointed, Lecturer B-Grade[9]. But, he actually availed the one year's leave with effect from 19th July 1938 instead of 20th July 1938[10]. The Council also considered a note from Dr. Saha requesting that the grant of Rs. 5,000 made by the U.P. Government for his researches should be continued during his absence on leave[11]. The Vice-Chancellor wrote to the Government for the continuance of the grant but it is not known whether his request was accepted or not. Dr. Saha also asked the University to give him the Duplicates of instruments on full payment of their price failing which he asked that instruments may be sent to him for a period of 2 years. The Executive Council resolved that the apparatus should be lent only when the application for it has been received from the Calcutta University on the following conditions[12, 13] :

(i) that the original apparatus should not be removed from the University Laboratory;

(ii) that the borrowing University make itself liable for any damage to the apparatus;

(iii) that the transit and all incidental charges should be borne by the University which borrows.

It was further resolved that such applications when received should be placed before the Executive Council. But he did not pursued the matter further. Perhaps he changed his mind as it would have been ridiculous to set up two rival laboratories for the same purposes. Also, at Calcutta the subject which he chose for himself was Nuclear Physics which had not at that time attracted much attention in India. Further, he also entered into the national politics in 1938. In the meantime, the Executive Council on 15th April 1939 further extended his leave without pay upto 31st March 1940[14]. By this time, it was crystal clear that Dr. Saha will not return to Allahabad. Hence, the University initiated the process for appointing Professor of Physics. Finally, Saha resigned his Professorship of Physics of Allahabad University on the expiry of his leave. The then Vice- Chancellor observed—''He had been Professor and Head of the Physics Department since 1923 and had also served for three years as Dean of the Faculty of Science. The University is sorry to lose the services of an eminent scholar who had done much to stimulate higher research and whose work in founding the Academy of Sciences (at Allahabad) has been of great value''[15]. The Executive Council accepted the resignation recording its warm appreciation of the services rendered by Dr. Saha during 1923 to 1940 at its meeting held on 27th April 1940[16]. At the same meeting, the Executive Council resolved that Prof. Erwin Schroedinger, Nobel Laureate, be appointed Professor of Physics on Rs. 1,000 or such higher salary as may be settled with the consent of the Government for a period of three years in the first instance. It was also resolved that failing him, Dr. K. S. Krishnan, F.R.S., be appointed in the grade 600-30-900-50-1,000 on such initial salary as may be settled[17]. Schroedinger accepted and an initial pay of Rs. 1,200 in the special scale of Rs. 1,000-50-1,500

for Schroedinger was settled in consultation with the Government of United Province[18]. The then Vice-Chancellor observed—" It is a matter of genuine satisfaction that the University has been able to secure the services of such an eminent scientist whose greatness is universally recognised[19]. But Schroedinger could not come out to join Physics Chair due to the onset of World War II [20].

6. Department During 1937-42

The Executive Council on 23rd January 1937 (Resolution No. 31) considered the demand from Saha to create a post of Licensed Wireless Operator. The work on Wireless Telegraphy and Broadcasting was already being carried out in the Department since 1926. The matter was also discussed in the meeting of April 10, 1937 (E. C. Resolution No. 71). Finally, Mr. Ram Ratan Bajpai, M.Sc. was appointed in the grade 60-3-90 with initial salary of Rs. 60[21]. But he went on leave with effect from 3rd February, 1939 to join Irrigation Research Institute, Lahore[22]. What happened thereafter is not known.

On 15th November, 1937 the Executive Council considered a letter from Mr. V. N. Vidyant, intimating that his father Late Hari Prasad Vidyant had asked him to endow $3^1/_2$ percent G.P. notes of the face value of Rs. 1,000/- each to the Allahabad University for the purpose of giving three Gold Medals every year and inquiring whether the University will accept the same. The offer of Mr. Vidyant was accepted[23]. Out of the three, two medals to be called "Ward Vidyant Memorial Gold Medals" and one to be called "Cox Vidyant medal". Dr. A. W. Ward was Professor of the Canning College, Lucknow and Homershan Cox was Professor of Mathematics of the Muir Central College. Story of Mr. H. P. Vidyant is interesting. He joined Muir Central College in 1892. He contemplated appearing for the M.A. in Physics as well simultaneously with Mathematics. Mr. Cox and Mr. Murray had no objection. He started attending lectures on M.A. (Physics) and also doing practical works. However, at the end of the term when examinations were approaching he was informed by the University authorities that he could not take two M.A. degrees the same year. So, he gave up Physics and confined himself entirely to the M.A. (Mathematics). "The Ward Vidyant Memorial Gold Medals" was to be awarded every year to the best students of the University in the M.Sc. and B.Sc. Examinations in Physics. The other medal was to be awarded to the best student in M.A. or M.Sc. Examinations in Mathematics every year. For many years these medals were awarded to the students but what happened afterwards is unknown[25, 26].

During the session 1936-37 Rai Bahadur Brij Lal Bhatia donated a sum of Rs. 1210/- to the Department. The amount was utilised in the construction of a room with heat proof ceiling which was henceforward be known after Lala Fakir Chand Bhatia, father of the donor[27]. This room is presently used for M.Sc. (Previous) Electronics Laboratory.

A course of Elementary Aeronautics was introduced in the syllabus of the B.Sc. Hons. Examination with a view to meet the growing needs of aviation[28].

On the occasion of the Golden Jubilee Celebrations of the University in December 1937, the Department arranged some interesting and instructive experiments for the public. Through the number of visitors was small yet those who visited felt pleased with what they saw[29].

On 26th April 1937 the Executive Council considered a proposal of Mr. Saligram Bhargava

for the starting of an Aero Club and its inauguration to be held on the Golden Jubilee day (Resolution No. 98). The matter was again discussed in the Executive Council on 18th September 1937 (Resolution No. 146) and on 3rd September 1938 (Resolution No. 179). It was proposed to ask the Government or the Cantonment authorities for use of the Chatham Lines Parade Ground as Aerodrome. Should this plot not be available, an attempt should be made to obtain the old Race Course. Saligram Bhargava even donated Rs. 10,000 for procuring an aeroplane[30]. But what happened ultimately to this proposal is not known.

The Physics Seminar started by Saha was revived during the session 1938-39. The Bulletin of the Physics Seminar was also published during the session 1939-40 perhaps for the first time. In Physics Seminar both students and teachers (both local and outstation) used to deliver lectures. In the session 1941-42, Prof. Sir C. V. Raman, the Nobel Laureate delivered 3 lectures in the Physics Seminar.

Thus, it is apparent that the Department remained active and vibrant even during the transition period 1937-42 when towering personalities like Saha and Krishnan were not there.

7. Bhabha's Refusal and Krishnan's Appointment

The Executive Council on 2nd August 1941 appointed Dr. H. J. Bhabha, F.R.S. as Professor of Physics[31], with an initial pay of Rs. 1,050 p.m. in the scale of Rs. 800-50-1250[32]. But on 10th Jan 1942, the Executive Council was informed that Dr. Bhabha is unable to join the post [33]. His refusal was due to his promotion to the post of Professor at Indian Institute of Science, Bangalore where he had been Reader in Theoretical Physics. So, the post of Professor of Physics was advertised. On 21st March 1942, the Executive Council decided to appoint Dr. K. S. Krishnan, D.Sc., F.R.S. as Professor of Physics with initial salary of Rs. 1250 p.m. in the grade of Rs. 800-50-1250 [34]. Prof. Krishnan was not unknown to Allahabad University. He had been the thesis examiner of D.Sc./D.Phil candidates and had already visited Allahabad for the viva voce examination of the same.

It is not clear how Bhabha's name cropped up for the post of Professor of Physics in between the appointment of Schroedinger failing him Dr. Krishnan on 27th April 1940 and the actual appointment of Dr. Krishnan on 21st March 1942. Prof. Krishnan joined as Professor of Physics on 24th March 1942. On his joining the then Vice-Chancellor had observed—'' Prof. K. S. Krishnan, F.R.S. has joined as Head of Physics Department. A scholar of his brilliance and teaching experience is a valuable acquisition and both teaching and research in Physics will much progress under his direction ''[35].

8. Department Under Krishnan's Headship

Staff : Although Krishnan's tenure as Head of the Physics Department (1942-47) was very short and the development of the laboratories was handicapped by Word War II, he took immense pain to gain the highest standards of teaching and to build up a research atmosphere of creditable values. To his utter dismay he found that while number of students increased, the total strength of teachers remained more or less stagnant at the same level as it was at the time of Saha's joining in 1923 : Enrolment of students in the Department is shown in the Table 1.

Table-1

1923-24			*1936-37*			*1941-42*			*1946-47*		
B.Sc.	M.Sc.	D.Phil/ D.Sc.	B.Sc.	M.Sc.	D.Phil D.Sc.	B.Sc.	M.Sc.	D.Phil D.Sc.	B.Sc.	M.Sc.	D.Phil D.Sc.
120	20	—	209	29	5	212	27	6	330	42	8

At the time of Krishnan's joining, the Faculty of the Department consisted of following persons:

1. Mr. Saligram Bhargava
2. Dr. R. N. Ghosh
3. Dr. G. R. Toshniwal
4. Dr. K. Majumdar
5. Dr. G. B. Deodhar
6. Dr. R. N. Rai
7. Dr. A. N. Tondon
8. Dr. B. C. Das

Naturally, he felt that teachers could not pay that personal attention to students so essential for the proper development of their mental, physical and moral faculties in a residential university. He, therefore tried to induct more teachers in the Department and was successful in getting Mr. Asutosh Mukherji appointed as additional temporary Lecturer in Physics due to increase in enrolment of students [36].

As a member of the Cadre Review Committee he suggested in 1944 that [37].

(i) When there is one Professorship (as in the Physics) in the cadre of any Department, an Associate Professorship may be sanctioned;

(ii) the designation of Associate Reader may be granted to a Lecturer who has specifically distinguished himself as scholar and teacher;

(iii) One Readership may be created in Physics;

(iv) on Mr. Bhargava's retirement, his post be split into two Readership;

(v) temporary Lecturership may be made permanent.

It was due to his sustained efforts that at the time of his leaving the Department the sanctioned strength was: 1 Professor, 1 Reader and 10 Lecturers [38].

During the session 1941-42 Dr. A. N. Tandon and Mr. R. N. Rai during the session 1942-43 resigned to take up new assignments and so Mr. Kundan Singh Singhvi in 1941-42 and Dr. Bishambhar Dayal Saxena in 1942-43 were appointed. In the next session 1943-44, the Department was further strengthened with appointment of Mr. Rajendra Singh (the present 'Sar Sanghchalak' of RSS popularly known as Rajju Bhaiya). During 1944-45 Mr. A. B. Bhatia was appointed. In 1945-46 Dr. G. R. Toshniwal was on leave to join the Meteorological Department and in his place Mr. Krishnaji was appointed temporary Lecturer. In 1946-47 Mr. Singhvi went on two years' leave to join Research Scholarship of the National Institute of Sciences of India (now INSA) and Dr. D. Sharma was appointed in his place. During 1947-48

Toshniwal resigned, Bhatia went to England and Mr. Hari Narain was appointed. Owing to increase in number of students an extra Lecturership was created to which Mr. Rudra Pal Singh was appointed.

Syllabus : Krishnan also devoted his attention towards the upgrading of syllabus and improvements in the conduct of examinations. As Chairman of the Committee of Courses and Studies in Physics he suggested the following [39] and got it implemented:

(i) that in all University examinations in Physics, the candidates be supplied Tables of Logarithms and of Physical constants (like Clark's Table) and they be permitted to use their own slide rules;

(ii) that the paper setters for University examinations in Physics be asked to send alongwith their question papers solutions for questions that involve numerical calculations. Such instructions should not be issued by the University to the examiners.

In 1945, in view of the large increase in the number of candidates taking the B.Sc. Practical Examination the number of examiners was increased from 2 to 4 (2 internal and 2 external). Further, in the M.Sc. (Final) Practical Examination, in view of different special subjects, usually three, offered by the candidates, the number of examiners was increased from 2 to 4 (3 internal and 1 external) [40].

Following changes were also effected in the syllabus of B.Sc. and M.Sc. [41].

B.Sc. : Following were added in the list of experiments :

1. Determination of viscosity of a liquid
2. Velocity of sound using oscillator
3. Nodal Slide
4. Verification of Brewster's law

M.Sc. : Theory : A mode detailed treatment of the topics in Magnetism was given in the syllabus of Modern Physics.

Practical : 1. Measurement of susceptibility of (a) diamagnetic gas (b) paramagnetic gas and (c) a liquid.

2. Determination of principal susceptibilities of (a) paramagnetic and (b) diamagnetic single crystals
3. Study of hypothesis of ferromagnetic substances with the cathode-ray oscillograph
4. Specific heat of nickel in the neighbourhood of its Curie temperature
5. Verdet constant
6. Hall effect in Bismuth
7. Magneto-optics : Kerr Effect
8. Magnetic double refraction of benzene
9. Zeeman and Inverse Zeeman Effects
10. Gyromagnetic ratios.

Photographic and Laboratory Workshop Training Classes : In 1938 Mr. Saligram Bhargava suggested a Scheme of Laboratory Workshop Training [42, 43] and starting of a Photographic Class[44]. He even donated Rs. 2000 for Workshop Training [45] and Rs. 300 for Photographic Class building [46]. Both the schemes were approved and Photographic as well as Workshop Training Classes were started from the session 1939-40 [47].

In 1942, to put the Workshop Training on a permanent footing the matter was referred to Finance Committee [48] and finally Mr. Kesho Ram Rastogi was appointed Workshop Instructor for the first time during Krishnan's tenure [49].

The question of placing Photographic class on permanent footing was deliberated upon by the Academic Council on March 6, 1945 (Resolution No. 11) and the Executive Council on March 24, 1945 (Resolution No. 46). The syllabus and Ordinances for the Certificate Examination in Photography was approved and the following Committee of Courses and Studies in Photography was constituted [50] :

1. Dr. K. S. Krishnan (Chairman)
2. Mr. Saligram Bhargava
3. Dr. Gorakh Prasad
4. Dr. K. Mazumdar
5. Mr. K. P. Chatterji
6. Dr. K. N. Mathur
7. Mr. S. H. H. Rizvi

On 18th October 1946 (Resolution No. 29 & 30) Faculty of Science considered the recommendation of the Committee of Courses and Studies in Photography the desirability of instituting a Diploma Course in Photography in addition to the ongoing Certificate course which was accepted by the Executive Council.

Physics Colloquium : Krishnan started during the session 1942-43 a Physics Colloquium for advanced students for reading original papers and discussion of special topics in Physics. This continued to function throughout his tenure and sometimes its meetings were held as frequently as twice a week. The Physics Colloquium was in addition to the Physics Seminar started by Saha.

9. Scholars Who Worked With Krishnan at Allahabad

There were many research scholars who worked under the guidance and supervision of Krishnan for their D.Phil or D.Sc. degree. Some of them alongwith their topics are listed below:

1. Mr. Ram Chandra Saxena : Atomic and Molecular Magnetism in Physics.
2. Prof. Ajit Ram Verma (He later became Professor and Head of the Physics Department, B.H.U., Varanasi and retired as Director of NPL) : Optical properties of single crystals in the Quartz and in the Fluorite in ultra violet regions.
3. Mr. Nageshwar Tripathi : Physics Spectroscopy.

4. Prof. Avadh Behari Bhatia (now settled in Alberta, Canada) : Physics of Metals and Alloys (the electrical resistivities of metals and alloys in solid and liquid state).
5. Mr. Sukumar Mazumdar : Physics of Metals and Alloys.
6. Mr. S. L. Chorghade : Crystal Physics (Optical Properties of Crystals.)
7. Mr. Narayana Rao : Dielectric Constants of Crystals.
8. Dr. (Miss) Chandra Kanta : Reflection and Absorption Coefficients of Graphite in the Visible and Ultra-Violet Regions of the Spectrum.
9. Prof. Harish Chandra (He later settled in Princeton and was one of the most brilliant mathematicians of the world) : Theoretical Physics.
10. Mr. V. G. Kher : Some Aspects of Crystal Physics.
11. Dr. Bajirao Vasudev Gokhale : Physics of Metals and Alloys (the optical constants of single crystals of some semiconductors).
12. Mr. B. S. Negi : Optical and Other Studies and Single Crystals.
13. Dr. S. B. L. Mathur, D.Sc: Thermal Ionisation (on thermionic work functions of metals and alloys).
14. Dr. Chandra Bhan Sharma : The absorption spectra of some diatomic molecules.
15. Mr. B. A. Subramaniam : Crystal Physics.
16. Mr. Rudra Pal Singh : Magnetism.
17. Mr. D. Venkatesan : Dielectric constants of crystals.
18. Mr. Kripa Narain : X-rays.
19. Mr. Shiva Kishore : Magnetism.
20. Dr. V. R. Ramanathan : Crystal Physics (The polarisation of absorption and fluorescence of some organic single crystal).
21. Dr. (Mrs.) Atasi Prabha Bose (nee Atasi Prabha Dey) : Electrical properties of single crystals of some semiconductor.

Obviously, Krishnan worked on a wide range of topics. The teaching assignment at Allahabad provided him the much needed opportunity to systematically review various problems of scattering of light, X-rays and electrons, statistical physics and thermodynamics as well as quantum theory and wave mechanics through a process of mutual discussions with seminar students. The panel of experts to examine the thesis of his students includes Prof. F. London (U.S.A.), Prof. Fowler, F.R.S. (Cambridge), Prof. Sydney Champman (London), Prof. C. W. Richardson, F.R.S. (London), Prof. N. F. Mott, F.R.S. (Bristol), Prof. C. G. Darwin, F.R.S. (Middlesex), Dr. W. Jevons (London), Prof. S. N. Bose, Prof. D. S. Kothari, Prof. Sir C. V. Raman, Dr. K. R. Ramanathan, Prof. N. S. Nagendra Nath, Prof. S. Bhagavantam, Prof. S. Chandrasekhar, F.R.S. Prof. R. K. Apundi and host of others.

10. Krishnan Appointed Founder Director of NPL

In October 1945, the University received a letter from the Deputy Educational Advisor, Department of Education, Government of India asking the University whether it will be possible

to spare Krishnan for deputation to U.K. and U.S.A. for about six months. The Executive Council on December 5, 1945 decided to place him on deputation on Government's sanctioning the payment of his salary [51]. Consequently, he went as a delegate of the Government of India to the Royal Society Commonwealth Conference held in London, Oxford and Cambridge in June-July and was also deputed by Government of India to visit various scientific laboratories and research institutions in Europe and America to study recent trends in Physics. The necessary study leave ex-India from July 16 to December 1, 1946 in continuation of the Summer Vocation was granted to him by the University [52] and an alternative arrangement was made for teaching and other works during his absence. The leave was further extended till the end of December 1946. During the study leave ex-India, Krishnan represented the University as a delegate to:

(i) the Conference on X-ray Crystallography held in London in June 1946;

(ii) the Conference on Fundamental Particles and on Low Temperatures held in Cambridge in July 1946;

(iii) the Newton Tercentenary Celebrations in London in July 1946;

(iv) the Zeeman Congress at Amsterdam in September 1946;

(v) the Bicentennial Conference of Princeton University, U.S.A. held in September 1946;

(vi) the Joint Meetings of the National Academy of Sciences, Washington and the American Philosophical Society in October 1946.

Before Krishnan left India on study tour he was also elected Chairman of the Applied Physics Committee of the Board of Scientific and Industrial Research, Government of India. After his return from abroad he was not able to devote much time to the affairs of the University as he was tipped off to shoulder an even bigger responsibilities. In March 1947 the University received a letter from the Director, Council of Scientific and Industrial Research for permission to appoint him as the Director of the newly established National Physical Laboratory, New Delhi from 1st April 1948. The Executive Council considered this letter on April 26, 1947 and resolved that Krishnan be permitted to accept the appointment. It was also resolved that during the session 1947-48, Krishnan be permitted to help in the work of NPL and to accept the honorarium of Rs. 500 for this additional work. Further, the council also decided to advertise the post of Professor of Physics in India and also in England and U.S.A. [53]. However, in view of the difficulties of the twin responsibilities he resigned in the meantime and his resignation was accepted with effect from June 9, 1947 [54]. On his resignation, the then Vice-Chancellor observed—"His departure from the University is a great loss. But, it is a matter of some satisfaction that his talent will have a wider scope in organising Physical research so necessary for the future of the country" [55]. It would not be out of place to mention that Sir Krishnan was followed by Dr. P. K. Kichlu and Prof. A. R. Verma. Later on Prof. S. K. Joshi also held the Directorship of NPL. And they are all almuni of this Department.

11. Knightwood and Honorary Doctorate of A.U. conferred on Krishnan :

In 1946 Knighthood was conferred on Prof. K. S. Krishnan in recognition of his distinguished contributions in Science [56]. The Diamond Jubilee Celebrations of the University was organised in 1947. A special convocation was held on December 13, 1947 and was presided over by Her Excellency, Shrimati Sarojini Naidu, the Chancellor. In this convocation Honorary Doctorate

Degree was conferred on Prof. Sir K. S. Krishnan alongwith Dr. Bidhan Chandra Ray, Mr. J. R. D. Tata, Sir Shanti Swarup Bhatnagar, Sir M. Visveswaraya, Prof. M. N. Saha and Prof. Birbal Sahni. While presenting the degree the then Vice-Chancellor, Dr. Tara Chand said—"I present to you Sir K. S. Krishnan, formerly Professor of Physics in the University, now Director of the National Physical Laboratory. He is a Fellow of the Royal Society of London and a teacher of distinction. His contributions to Optics, Magnetism and the Physics of Metals and his collaboration in the discovery of the Raman Effect entitle him to a distinguished position among scientists. I pray that the degree of Doctor of Science, *honoris causa,* be conferred on Sir K. S. Krishnan." It was really a momentous occasion that two of our former Heads of the Physics Department were conferred the degree of Doctorate on the occasion of Diamond Jubilee Celebrations" [57].

Epilogue

Krishnan was a great scientist, very modest and deeply simple, soft spoken and courteous who worked hard to make the Department of Physics well known throughout the world in the realm of crystallography and other areas of modern science. On the occasion of his birth Centenary and Platinum Jubilee of the Department we must pledge to keep his tradition of excellence flowing.

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PROMOTING PHYSICS RESEARCH IN INDIAN UNIVERSITIES

A. K. Mittal

"Physics is the 'science of wealth creation' par excellence". To appreciate this statement of Abdus Salam, one only has to look at the revolutionary developments in Physics during the last century, and the role they have played in the rapid economic progress of the world. Therefore the importance of Physics Research for converting developing countries into developed ones cannot be overemphasized.

The developing countries, however, cannot easily spare resources for research, as there are more pressing and immediate demands to be satisfied. This leads to a vicious cycle. The dependence of the developing nations on the developed nations for know how and finished goods goes on increasing. This leads to greater and greater indebtedness. If one has to get out of this vicious cycle, there is no option but to invest in research in a pragmatic and well directed manner.

During the last two decades, there has been substantial increase in the funds available for Physics Research. However, one does not feel that this will have the desired effect of reducing dependence on the developed world. In fact the trend seems to suggest the opposite. The basic reason, is that the research funding seems to be directed towards buildings and equipment without matching emphasis on identifying individuals having high aptitude for research in Physics, motivating them, training them and retaining them in Indian Universities.

The biggest hurdle is absence of career prospects comparable to the alternatives available. Jobs in Physics Research should be made at least as lucrative as the alternative career options available to bright students passing out of our schools and intermediate colleges. Surveys about the career preferences of these students should be conducted and remedial steps should be taken to ensure that promising students are not lost to other professions, where they are misfits, or at best, where there is relatively less need for their talents. In order to encourage research and scholarship, the government has proposed that eminent Professors of the country be declared Professors of Eminence and given 'very high pay'. The proposed pay even for these eminent persons is far less than what people in administrative services reach as a matter of routine. Surely present and future Krishnans of the country deserve the highest pay scales in the country. Professors of Eminence should be given the highest salaries in the country. This may encourage bright students to opt for teaching and research careers.

The National Board of Higher Mathematics conducts Mathematics Olympiad examination to identify school students having high aptitude for Mathematics Research. Almost all the students chosen by these tests also get selected to the IIT's and join engineering courses. Every year, for one month, the National Board of Higher Mathematics helps train these students for

Mathematics Research. Such schemes are useful, as they will no doubt improve the caliber of these budding engineers. But they fail to address the problem of failure to attract even a small proportion of these bright students into our Universities for Higher Education and Research in Mathematics. Indian Association of Physics Teachers (IAPT) has been conducting examinations in Physics for helping students identify their aptitude for Physics. But no attempts have been made to identify the causes why these promising students do not opt for Higher Education and Research in Physics. IAPT has drawn up a scheme to identify students for participation in International Physics Olympiads. There is little doubt that almost all the students so identified will also opt for engineering courses. The efforts to identify promising students having aptitude for Physics will have no more beneficial effect than to add a few more feathers into the caps of these students. It is essential to ensure attractive career openings, so that a fair share of bright students may opt for Higher Education and Research in Physics. It is pertinent to note in this context that a bulk of these engineers will not even perform for the country as engineers. In 1997, of the first 20 selections for the Indian Administrative Service, 18 were engineers. Thus the resources that went into nurturing their talent for Mathematics. Physics and Technology did not further India's goals of developing self sufficiency.

The bulk of the research funding goes to the few research institutes, whereas the universities are relatively starved for funds. This has been one of the causes of poor motivation and training of students in the Universities. Promoting research in Universities is important so that students get exposure to research frontiers from an early age. The research institutes have excellent facilities but few users, whereas the Universities are poor in facilities but have a large number of potential users. The cost of books and research journals has become so prohibitive that almost none of the Universities can afford the kind of libraries necessary for promoting quality research. Efforts should be made for international collaboration so that bulk supply of books and journals can be made possible at low costs taking advantage of economies of scale. Teachers and students of universities should be provided facilities so that they can make use of the few equipped libraries in the country. Low cost Physics periodicals such as Physics Education, Physics journals and Physics books published in India should be available in the libraries of Universities and Colleges throughout the country. With wide dissemination the cost-benefit ratio of these efforts will come down significantly.

Research funding for universities must be accompanied with a training and manpower development component. Career planning should accompany this manpower development, to ensure that promising youngsters find research careers attractive. This is particularly important in the case of high cost research projects. There are cases where the cost of equipment exceeds the cost of personnel by orders of magnitude. Suppose a University teacher, by virtue of his own standing, is sanctioned a project requiring equipment worth about fifty times his annual salary. Such a huge expenditure on equipment must be accompanied with a plan for growth around this physicist and the equipment. Students should be made aware of the potential of the equipment and encouraged to make use of the equipment. It is futile to make such huge expenditure without ensuring that they become a catalyst for exponential growth in production and utilization of people with the requisite knowledge and skills. When expensive equipment is purchased without matching investment in manpower, the equipment does not get optimally utilized. Whenever such expensive projects are sanctioned there must be well thought out long term plans, so that the expenditure can deliver commensurate benefits.

Research in Universities cannot be sustained in the absence of well planned and assured rapid expansion plans for higher education and research. In modern times Physics research has been transforming more and more from an individual activity to a group activity. Quality research requires growth of viable large groups and team work. This is particularly true for research in development areas where the basic ideas and framework are reasonably well established. Research also leads to several new fields and directions. Unless sufficiently lucrative careers are ensured for people trained in research, quite obviously quality manpower will not be attracted towards research. In the absence of quality manpower in sufficient numbers, the research efforts will fail to stem the economic dependence of the country on the advanced nations.

Students should be made aware of the research facilities available in their departments, in their near neighborhood, in their state and in the country. They should be made to appreciate the role and importance of Physics research for economic self- sufficiency of the country. They should be encouraged in the skills of problem solving and creativity, rather than waste their energies and time cramming for examinations. Part of their training must involve participation in the ongoing research programs of the Department. Research interests of Physicists usually begin with and develop throughout their lives around some question in which they got interested fairly early in life. Researchers must endeavour to disseminate information about their research goals and methodology to young students at their level of understanding.

Next in importance to manpower planning is the problem of delays in sanctioning of projects as well as in the actual availability of funds for utilization. Research has become an amazingly fast activity. There is not much time available between the inception of a plan based upon ideas and the execution of this plan. Even very eminent Physicists in the Universities have been heard complaining about the deleterious effects of administrative apathy towards research in Universities. Funding agencies must listen to the woes of the researchers in the Universities and find ways and means for sanctioning of projects. University administrative personnel responsible for handling the research projects should be sensitized about the importance of time in research and about their role in promoting research endeavors for national development. Universities should have research promotion cells to look into the problems of research and suggest remedial measures.

Formal teaching load on University teachers should be reduced, so that they have more time for research. Students should also be given more time for self-study and encouraged to carry out small projects. Teachers should have funds at their disposal to facilitate such small projects.

Research has several goals. Different types of research suffer from different types of problems. These differences should be appreciated and differing strategies should be adopted according to the differing requirements. There is a feeling that basic research is being neglected at the cost of so called 'applied' or 'relevant' research. It must be realized that merely because a research topic falls in a category rich in applications, does not mean that research in that topic will lead to great economic benefits. In the absence of proper planning and strategies, most of the research, whether 'basic' or 'applied' is irrelevant to the national goals. Basic research is curiosity driven. History of Physics shows the importance of this type of research. The economic fall out of such researches in the long term easily outstrip the benefits of purpose specific research. Therefore there has to be a continually increasing support for basic research

so that an exponential growth can be maintained. Applied research requires a more concerted effort in order to reap economic benefits. Whether basic or applied is not of importance. The important thing is to distinguish between significant research, insignificant research and bogus research. Research management policies should encourage significant research in a spirit of cooperation rather than insignificant and bogus research in a competitive spirit.

There is a need for clarity of goals and a matching of all the inputs necessary for Physics Research—financial, brainpower, time, team spirit, morale, administrative support etc. Such an integrated purposive approach is necessary to create a meaningful research atmosphere in the Universities.

Allahabad University lost Krishnan when he was called upon to set up the National Physical Laboratory. Perhaps the time has now come to call upon eminent Physicists in the research institutions to join the Universities and rejuvenate Physics Education and Research.

SCIENTIFIC RESEARCH IN INDIAN UNIVERSITIES – CASE OF MISSING FEEDBACK LOOPS

Chandra Mohan Bhandari

The concept and meaning of a university has never been fully realized and appreciated in India, particularly during post-independence era. Prior to that the motivation of the British government had been to create certain infra-structures for specific purposes. Even today the pattern of working of these institutions is much the same as during British period but the notion that a university is a self-organising system which in the longer run must be able to regulate its working, has never been realized. A systemic approach for understanding and solving the problems of such institutions is the need of the day and that can be achieved only through sincere efforts on the part of the policy makers. The single most important factor which is responsible for this state of affairs is the near absence of healthy feedback loops without which no living system can operate.

In a country like India with over one hundred and fifty universities a uniform pattern of academic and research activities may be difficult to define. The difficulty does not essentially arise from the vastness of the number of institutions but from the diversity for which this country is too well known. However, within a reasonable limit it should be possible to consider the whole set of institutions. Things may be different at various levels of planning and performance but the underlying current of universality and fundamental principles are sufficient to bind them together. An imposed unity of planning and performance is not essential if one does not compromise for the quality. In this essay an effort is being made to define and analyse the problem in the context of the basic philosophy of organisation.

A university is supposed to be a place for academic and research activities flourishing at various levels, a place where knowledge is shared with constant effort at searching new horizons. It is also a place where men of learning are in continuous and extensive interaction with young minds with an aim to acquire knowledge. In the longer run they do have the responsibility of sharing the fruits of the acquired knowledge for the good of the society. To maintain such an institution taxpayers' money has to be utilised. The cost is not unwelcome if within limits and if useful work is being done. However, at times this is not possible and the institution gradually degenerates into an "entropy state". These considerations must be taken care of in the scheme of things. However, these considerations are almost completely ignored; what is all the more disturbing is the fact that the intelligentsia has never given a serious thought to analysing and solving the problems pertaining to higher education and research.

SYSTEMIC APPROACH

Any research activity whether pure or applied, whether theoretical or experimental must

have a purpose from the perspective of the planner as well as that of the researcher. For an individual researcher it could be search for knowledge. This may be rare but it is not impossible. There are other perspectives too. The research could be oriented so as to seek a technological base and its consequent refinement, to create an infrastructure for future development and to provide necessary knowhow for the existing technology. One of the possible aims of education and research could be to provide trained manpower to run the 'second wave' society, as Alvin Toffler puts it. Whatever be the primary concern of the research the researcher has also a responsibility. I take liberty to quote Professor C.V. Raman : "The true role of scientists is the discovery of truth. They have no concern with the application or misapplication of the results of scientific discoveries. All the same, scientists owed an obligation to the society, to improve it".

GROUP ACTIVITY AND INDIVIDUALISM

Present day scientific research usually requires a sustained team work. Research groups should have an optimum size—neither too large, nor too small. Too large groups become unmanageable; too small groups are unable to provide a sustained chain reaction. Rresearch activity can be compared to the burning of coal. Coal pieces should neither be too close to restrict flow of air, nor should they be too far apart to miss the mutual warming effect. A rough estimate puts the number around 6 to 15 for usual kind of team work. In many of universities each person is an institution by himself. There are many faculties where not even two faculty members work jointly. In some cases team work is apparently there, but other members are usually research students working for Ph.D. degree. These youngmen are mobile, and usually start looking for jobs immediately after they obtain the degrees. This kind of team provides the quantity, but quality is hard to come by unless sustained and motivated effort is continued. If a graph is plotted with the number of Nobel laureates (in science) won by a country against the number of research papers published during the past 50 years, a proportionality is seen between the two. Some points representing countries such as India fall far away from the line. Of course, Nobel Prize is not the only and the best criterion to judge the quality. There could be other criteria too.

RESEARCH ENVIRONMENT

Talking of the research environment in our institutions it is not difficult to observe the cases of individual excellence in various areas. These men and women are comparable to the best anywhere in the world. On the other hand one finds very few examples of excellent group activity. There are very few schools of scientific research worth the name. In the first three decades of the twentieth century there was a period of creativity in and around Calcutta. Jagdish Chandra Bose, C.V. Raman, Satyendra Nath Bose, Meghnad Saha, K.S. Krishnan —the greatest among Indian scientists grew and flourished in a highly creative environment. Yet we find that these were individuals motivated by the creative urge and a supporting atmosphere no doubt but were not part of any school. There are no other names and no significant research activity in their respective areas after them.

Science is a kind of chain reaction. One idea leads to another and the story goes on. A nuclear chain reaction is familiar to us. There are certain conditions for the chain reaction to be sustained. One neutron participating in the reaction must be able to produce more than one

of its kind before calling it a day. For that a critical mass is required. These ideas can be very well applicable to social systems including the working of an institution.

DISSIPATIVE STRUCTURES

Living systems differ from the simple physical systems in several ways; they are self-organising and require multiple feedback loops for their survival. In the context of thermodynamics there is a special kind of difference. A physical system has a tendency to acquire a state of equilibrium if left to itself. Thermal equilibrium will mean that all parts of the system acquire the same final temperature. Similarly one can define chemical equilibrium and mechanical equilibrium. Living systems are different from such systems; they operate not in equilibrium, but operate far from equilibrium. A piece of furniture left in a room for sometime will acquire the temperature of the room. Living in the same room we have a different body temperature.

To maintain a living system far from equilibrium energy has to be constantly supplied to it from outside. A part of that energy goes waste. It becomes unproductive. That means the available energy for useful work is being reduced. This kind of degradation in living systems is also known as dissipation and such structures are known as dissipative structures.

Social systems are living systems in continual interaction with the environment and are therefore placed in the category of dissipative structures. Sometime it happens that the dissipation increases uncontrollably. In an economy the cost of the unproductive work may be called dissipative . Large bureaucracy is for example one such thing. Hazel Henderson has coined a term "entropy state" for that stage of economic development in which the cost of unproductive work exceeds the total productive capacity. Many of our social systems have today become entropy systems. Many departments in the government are examples of entropy states.

Most of our institutions have become too much dissipative. The feedback loops are missing or if they are not, their working is inefficient. What purpose an institution is supposed to serve? What are the resources and money input? How close does one get to the aim at the end of the session or a certain period? Such questions are rarely asked? Even more rare are the answers. There are examples where costly equipment worth 20 to 30 lakhs have been purchased and then dumped. Such cases are not exceptional, they are quite common. This is a criminal waste and a burden on the taxpayer. There has been no monitoring followed by a proper action. Many institutions including universities are in that category. Present day educationists and economists can not afford to ignore the study of such dissipative structures and the means to reduce the dissipation.

ANALYSING THE SITUATION

Why does this happen? It is not at all difficult to analyse the reason although it is not at all easy to solve the problem. A living system is characterised by self organisation. Order must evolve within the system. For this feedback loops are essential.

Growth and stability mark the features of all living systems including institutions. Feedback loops ensure both the features. Positive feedback helps in the controlled growth whereas the

negative feedback is necessary for the stability of the system. In all healthy institutions such loops are not only present, they are in good working condition too. The concept of reward and punishment is an old one. This is a kind of simple feedback. Reward is a kind of positive feedback whereas punishment is a kind of negative feedback. There can be finer and more complex looping patterns. The purpose and the working mechanism of the loops must be well understood by policy planners.

TALENT, ITS SEARCH AND AFTER

Motivation of the researcher (new entrants in particular) is important. Scientific research should be planned so as to attract the best talent of the nation. Novel schemes have often been implanted into the planning of scientific education and research from time to time. From a distance some of these look impressive, yet looked closely one wonders why afterall we are not being able to manage our affairs. The case under scrutiny could be that of National Talent Search (NTS) programme. For this search a three tier nationwide evaluation at the matriculation level is organised. Whatever be the methodology of defining and searching national talent, once it has been identified it needs to be nurtured well. The way it is done reduces the whole thing to a farce.

The scholarship provided to a pre university student is Rs. 200 and to a university level student it is Rs.300 per month. Those who generally qualify for the scholarship come from middle income group families and for them the amount reduces to Rs. 100 and Rs. 150 respectively. A student who joins IIT pays between 25,000-35,000/- per annum as tuition fee. The talented student after qualifying the nationwide search gets scholarship amounting to Rs.1800/- per annum. Can anyone explain the meaning and purpose of the whole exercise. The decision to let these institutions generate their own resources and funds was a bit hasty and crude. Whereas a reasonable fee hike could be acceptable, an order of magnitude hike in fees will have a long ranging negative impact on the motivation and working of young minds. Some such effects are already coming to surface,

Can this be called planning ? Most of our prestigious institutions including IIT's are just degree providing units. How many graduates from the prestigious IIT's join in a R and D programme? Not even 1 per cent. Most of them take up administrative and management jobs. Have all these points been monitored ? Has there been some follow up action to arrest this trend ? Is it not a national wastage ? Can a poor country afford it?

IN CONCLUSION

These ideas are based upon very simple considerations. No expert knowledge is required to understand and implement such simple feedback loops. If the working of an institution is to be improved then the first step should be to allow such feedback loops to function. Once this is done expert opinion can be sought to analyse the pattern of working. This brings the need to incorporate into the system the well accepted norm of accountability. Social chain reactions are important in any creative work and tradition. An understanding of their working coupled with the understanding of human psychology can help a lot in deciding a programme for action. Other aspects of social engineering can then be incorporated into the scheme of things.

SECTION 3

THE UNIVERSITY

AND

DEPARTMENT OF PHYSICS

- *Allahabad*
- *University of Allahabad*
- *Department of Physics*
- *Research Activities of Physics Department*

ALLAHABAD

One of the oldest cities of India, Allahabad is also known as Prayag. The earliest reference of the city can probably be traced to *Skand Puran* according to which in the beginning of the creation Brahma performed a *yagna* (prakrista yagna) and hence the name Prayag. Obviously the city acquired a prominent place in the Hindu religious texts. The confluence of the three sacred rivers, Ganga, Yamuna and the mythical Saraswati, marks the religious importance of the city. For this very reason the city is also known by the name "Triveni". The sanctity of the confluence has been derived from the belief that Indra dropped a few drops of the divine nectar on this spot when he was taking away the precious pitcher from the demons. The pitcher was found among several other things, from the churning of the oceans. The highlight of the religious significance of the place is apparent even today; every year a month long bathing festival, "Magh Mela", is held which is a part of the city's cultural life. Every twelfth year the occasion is marked by "Kumbh,"; which is so far the largest human gathering anywhere in the world.

There are innumerable reference of the city in the religious text. Satpatha Brahmana, Mahabharat, and Ramayana have made a reference of the city on several occasions. Lord Rama while in exile visited the famous" Bhardwaj Ashram" at Prayag and crossed the river Ganga on his onward journey.

Gradually the city acquired prominence in several other contexts. The region around the city appears to be one of the oldest human habitats in the country. The valleys of the river Belan and Son have yielded evidence of the continuous presence of man from the lower paleolithic to the chalcolithic. Several neolithic sites are located in the district of Allahabad. These and several other archaeological findings were brought into light by the archaeologists of the Department of Ancient History, Culture and Archaeology, University of Allahabad.

For a long time the fate of Allahabad remained linked with the kingdom of Magadh (5^{th} century B.C. to 6^{th} century A.D.), During the reign of Harsha in the 7th century A.D. the region became a part of the kingdom of Kannauj. Every five years Harsha participated in the religious festivals at Prayag. Hwen Tsang, the Chinese pilgrim and scholar, has made a detailed reference of this in his writings.

After the Muslim occupation in northern India the history of Prayag was conditioned and manipulated by the rulers in Delhi. Akbar, the great Mughal (1556-1605) laid the foundation of the present city of Allahabad, and gave its present name. He also got a fort constructed near the confluence. It was made the provincial head quarter of the newly organised '*suba*'. In 1597 prince Daniyal was appointed the subedar but his loyalty to his father was not above board. Meanwhile taking advantage of Daniyal's absence the prince Salim (later Emperor Jehangir) captured the city. However, a reconciliation between the prince and the emperor was brought about. The trouble continued and differences arose between Salem and his son Khusro. The later rebelled his father and was imprisoned and was made blend. After his death in 1622 his body was sent to Allahabad for burial. The garden containing his tomb bears his name.

Allahabad again figured when prince Khurram (later emperor Shah Jehan) rebelled against his father Jehangir. Shah Jehan besieged the fort at Allahabad but was defeated by the imperial forces. Humbled and defeated he asked for pardon which was eventually granted. Allahabad again figured in the war of succession. During the decline of Mughal power Marathas raided the city (1739 and 1742).

The rise of the East India company brought the city into its fold when the Treaty of Allahabad gave the Company right to station its troops there. In 1801 the British subsequently took over the city and made it an important military base. After the revolt of 1857 which was ruthlessly suppressed, Allahabad became the capital of the province. Meanwhile other important events marked the beginning of the emergence of Allahabad as an important city in the years to come. The high court was established in 1868, and the Muir Central College in 1872. In the year 1887 the University of Allahabad came into existence. With only four universities in the entire country at the time, including the one at Allahabad, the city gradually became an important educational centre.

It was natural that a city like Allahabad should have played an important role in the nations' freedom struggle. In 1888 the session of the Indian National Congress was held at Allahabad. In the decades preceding the independence Anand Bhawan had become the nerve centre of the political activities. Ayodhyanath Kunjru, Madan Mohan Malviya, Tej Bahadur Sapru, Motilal Nehru, C.Y. Chintamani, Jawahar Lal Nehru, H. N. Kunjru, Lal Bahadur Shastri, and a galaxy of other leaders from Allahabad have played a significant role in our freedom struggle. Some of these leaders led the destiny of the nation even after independence. The city has also contributed significantly to the development of modern Hindi literature. The names of Nirala, Sumitra Nandan Pant, Mahadevi Verma, Ila Chandra Joshi, and several other prominent writers are intimately linked with the cultural history of the city. There have been four "Gyanpeeth Award" winners from Allahabad including Sri Naresh Mehta.

Besides the university, the city can boast of several prestigious institutions. Prayag Sangeet Samiti is one of the renowned institutions dedicated to the teaching of Indian Classical Music and Dances. Mehta Research Institute of Mathematical Science and Govind Ballabh Pant Institute of Social Sciences are among the prestigious institutions in their respective areas. The National Academy of Science, Allahabad, established more than six decades ago, has since been playing an active role in the cultivation and promotion of science. Hindi Sahitya Sammelan is yet another renowned institution dedicated to the cause of Hindi language.

Known for its academic and literary traditions the city has over the decades made its mark on the industrial map of the province. There has been a gradual industrialization of the city and its surrounding areas.

ALLAHABAD

PLACES OF INTEREST

Ashoka Pillar: Made of polished sandstone (10.6m high), the pillar inside the fort was made in 232 B.C.; edicts of Ashoka, record of victories of Samudragupta.

Anand Bhawan: Home of Nehru family; many momentous events related to the freedom struggle took place; now a museum depicting important events of Nehru family.

Akshaivata (The undying tree): Inside the fort. The tree stands in deep niche above an underground shaft, it is said, leads to Triveni. The tree is immortal according to Hindu scriptures.

Allahabad Museum: It has 18 galleries displaying articles from 3rd century B.C., including terra-cotta, coins, idols; paintings of Mughal, Rajasthani and Pahari schools.

All Saints Cathedral: One of the finest cathedrals in stone structure. Designed more than a century ago by William Emerson, the architect of the Victoria Memorial, Calcutta.

Bhardwaj Ashram: Legendary Ashram of Rishi Bhardwaj, visited by Lord Rama along with Sita and Laxman.

Botanical Garden: Under the Botanical Survey of India it has an experimental garden comprising of Ornamental section, Medicinal Plants, Green House and Arboretum. The Herbarium comprises of flowering plants and pteridophytes. Collection of plants from M.P. and U.P.

Chandra Sekhar Azad Park: Close to the Muir central College; statue of the great freedom fighter who laid his life here fighting against the British forces.

Hanuman Temple: Near the Sangam a unique temple with the deity of Lord Hanuman in lying posture. The deity is a few feet below the ground level. It is said that every year the river Ganga at least once floods the temple. People believe that Ganga comes there to touch the feet of Hanuman.

Fort situated on the bank of yamuna near Sangam; Built by Akbar.

Jawahar Planetarium: Built recently, the planetarium organises several shows everyday,. excluding Mondays.

Khusro Bagh: Tomb of Khusru, son of Salim. There is a big garden around.

Minto Park: On the bank of Yamuna, the park is now known as Madan Mohan Malviya Park. A white stone memorial with four lions symbol on top. Foundation laid by Lord Minto in 1910

Nehru Park: The famous McPherson lake situated at the bank of river Ganga in the western part of the city has been developed into a large park with fountains, natural landscape and boating facilities in the lake.

Sangam: The sacred confluence of Ganga, Yamuna and mythical Saraswati. Fascinating view at sunrise and sunset. World's largest human gathering held here in every Kumbh Mela.

Shiv Kuti: On the bank of Ganga. A fair is held in July-August. Situated nearby the Narayani Ashram with some excellent temples.

St. Joseph's Cathedral: Situated near the university. It has beautiful statues from Christian religious mythology.

UNIVERSITY OF ALLAHABAD

THE BEGINNING

In the year 1872 the Allahabad College came into existence as an associated college of the Calcutta University. Only Arts and Law were included in its curriculum. The college was soon renamed after Sir William Muir, the then Lieutenant Governor of North Western Provinces , who made pioneering effort to establish a university at Allahabad. The new building of the Muir Central College was inaugurated by the Viceroy Lord Dufferin, on April 08, 1886. The University of Allahabad came into existence on September 23,1887, with the passage of Act XVIII. The first ever examination of the university were held in 1889.

In 1894 the Faculty of Science was established. As an affiliating and examining body, the university acquired a vast catchment area in north and central India. The next important milestone in the life of the university came with the Indian University Act of 1904. This also, among other things marked the beginning of the residential and teaching character of the university. A new campus was developed between 1910 and 1916 which comprised the Senate House, Library and Law College buildings. The creation of Banaras, Lucknow and Aligarh Universities between 1915 and 1920 , the establishment of U.P. Board of High School and Intermediate Education in 1921, and the passage of Allahabad University Act of 1921 were among other events that led to a reorganised University of Allahabad by 1922. With the transfer of responsibility for the pre- university , Secondary examination to the U.P. Board of High School and Intermediate Education followed by the transfer of a large number of affiliated colleges to the newly created Agra University in 1927 the University of Allahabad became a unitary, residential teaching and research institution. As expected this was followed by steady academic progress in several spheres of the university life.

YEARS OF GROWTH

On reorganisation the Faculty of Science was set up in the picturesque area of the Muir Central College. New teaching departments were created and research work of highest standards was pursued by a galaxy of dedicated workers who projected the university to a leading position in India. The Golden Age of the university had virtually begun. Eager students from all over the region flocked into the portals of the university adding their own might to the enriching of the academic life of the institution. A number of dedicated researchers and teachers from all over the region saw in this university a good academic and research environment and decided to stay for good. It was during this period that men of the eminence of Neel Ratan Dhar, A.C.Banerji and Meghnad Saha joined the university.

THE FACULTY OF SCIENCE

The Department of Mathematics and Statistics is one of the oldest departments of the

present Faculty of Science with the Mathematics wing dating back to 1872, when Muir central College came into existence. In the initial stages the department was served by dedicated mathematicians like Professors Elliot, W.N. Boutflower, H. Cox, Ganesh Prasad and R.H. Moody. Professor A. Harrison, the first Principal of the Muir Central College also used to lecture in the department. The department of Zoology is another of the oldest departments in the faculty. In the first decade of the twentieth century it grew as a university from the erstwhile department of Biology of the Provincial Service . The year 1921 saw the establishment of the department of Chemistry followed by the Departments of Physics and Botany in 1923. Professor Meghnad Saha joined the Department of Physics from its very inception and very soon established a strong research group. His pioneering work on thermal ionization needed confirmation and he along with a group of dedicated workers decided to set up a laboratory with very meager finances. The laboratory was set up and the results confirmed. Saha was honoured with the fellowship of the Royal Society.

The Department of Botany started as separate entity in 1923 with Professor Julian H. Mitter as the founder Head. In spite of inadequate financial resources, the Department marched towards progress in undergraduate and postgraduate teaching and research. A postgraduate course in Agricultural Botany was introduced in 1944. During recent past a leading and internationally reputed school in Palaeobotany has been established.

During the twenties and thirties the department of chemistry too became known for research schools in the areas of Natural Product Chemistry, Coordination Chemistry, Reaction Kinetics and Soil Sciences Mention must be made in this regard of the pioneering efforts of Professors N. R. Dhar and S. Dutt. The year 1935 witnessed the foundation of the Sheila Dhar Institute of Soil Science (under the Chemistry Department) by Professor Dhar after the name of his wife Mrs. Sheila Dhar.

The steady growth of the research activities in several departments continued and within three decades of its reorganisation in 1923. Allahabad University established itself as a premier research- cum-teaching institution in the country. Several of its faculty members were honoured with the Fellowship of the Royal Society. In addition to those already mentioned other eminent scientist were : Professor K. S. Krishnan (Physics) and Professor P. Maheshwari (Botany). In spite of inadequate funding of the research projects a galaxy of dedicated researchers continued in their tireless efforts to push the frontiers in their respective fields ahead. It was an age of creativity in the life of the institution. The names of the Professor Meghnad Saha and Neel Ratan Dhar were nominated for the Nobel Award, although none of them was fortunate enough to get the award. Professor Dhar was a member of the Nobel Award Committee.

It was Professor Saha who mooted, for the first time in the country, the idea of founding an Academy of Sciences. The then Governor of the United provinces of Agra and Oudh, Sir Malcolm Haily encouraged the idea and promised help. The first Science Academy of the country came into existence under the name of " The Academy of Sciences of United Provinces of Agra and Oudh" in 1930. Professor Saha was elected its first President , Professors N. S. Dhar and K.N. Bahl were Vice-Presidents.

The process of growth and expansion saw the emergence of several new Departments. The Department of Home Science was started in 1945 with a two year degree course in B.Sc. Home Science. During the 4th five year plan postgraduate courses in Biochemistry were also

started in the department. In 1956, the J.K. Institute of Applied Physics and Technology came into existence. The decision of setting up such an institute could materialise when Sir Padampat Singhania, Chairman, J.K. Charitable Trust, donated Rs. 5 lakhs for the building and the Union Government donated a handsome amount for the equipment. The University took a lead in introducing Defence Studies at the postgraduate and research level in 1965. The year 1968 saw the expansion of Mathematics Department with the addition of Statistics wing, and Statistics as a subject was introduced at undergraduate and postgraduate levels. In 1985 three year degree course was also started. The latest addition to the expansion programme of the faculty of Science came into being with the establishment of the Department of Earth and Planetary Science in 1985.

THE CHALLENGES

Continuous expansion in the scope and activities invariably brought focus crises and problems. After independence new institutions emerged all over the country and a large number of eminent researchers left Allahabad to take up greater responsibilities. The emergence of prestigious Institutes of Technology and a general neglect of the established premier institutions like Allahabad, and unplanned expansion to cope with the emerging pressures, were some of the reasons for various problems being faced by the university.

Looking Ahead

The University of Allahabad completed one hundred years of its existence in 1987. In the course of its history the University has faced several problems and challenges, but has managed to handle the situations by its resilience and determination. It has over the decades fulfilled its obligations commendably and played a role in all spheres of the national life, be it science and technology, politics, literature, administration or management. The present day problems related to financial and administrative matters are not by any means insurmountable. With a determined bid on the part of the government and the faculty the University could not only regain its status as a premier institution, it would play a much more determined and effective role in the academic life of the nation. Some of its illustrious alumni like Professor Meghnad Saha did emphasize in no uncertain terms the social dimensions of science and he himself worked tirelessly to achieve that end.

PRESENT DEPARTMENTS OF THE FACULTY OF SCIENCE

The Faculty of Science over the six decades expanded considerably in its scope and range of activity. A present the research and teaching activities are being taken care of by the following departments:

Department of Mathematics and Statistics
Department of Physics
J.K. Institute of Electronics and Communication
Department of Earth and Planetary Science
Department of Chemistry
Department of Botany
Department of Biochemistry and Home Science
Department of Zoology

DEPARTMENT OF PHYSICS

Started in 1923 the Department of Physics has a glorious history. It has the proud privilege of being guided by stalwarts like Prof. M. N. Saha and Prof. K. S. Krishnan. Both were honoured with the Fellowship of Royal Society. The alumni of this department occupy important positions in almost every sphere of nation's life. Among them are renowned scientists, Professors in various universities and institutes, Directors of national laboratories, governors, ministers and a galaxy of able administrators. It would be not out of place to mention that with one exception, all the Directors of the National Physical Laboratory (until 1990) were the alumni of this department.

Led by Professor Saha and small group of teachers, the research activity of the department started with spectroscopic investigations, the primary concern being the study of thermal ionization. The work progressed well and in 1927 Saha was honoured with the Fellowship of the Royal Society for his contributions primarily that on thermal ionization. Soon after X-ray crystallography and X-ray spectroscopy were also included in the research agenda of the department. At one time the X-ray laboratory of the department was the best in this country and was recognized internationally. In due course the Microwave Laboratory shot into prominence with most of the vital microwave and electrical units indigenously designed and fabricated in the departmental workshop. Primary emphasis of the group was in the study of dielectric properties, line broadening, microwave spectroscopy and ESR. Almost around the same time Ultrasonic Laboratory came into existence with the study of ultrasonic absorption and velocity measurements in a wide frequency region.

During the fifties and early sixties theoretical groups emerged with studies in Condensed Matter and Particle Physics. The Condensed Matter Theory group was initially concerned with the aspects of lattice dynamics and thermal transport in semiconductors. Gradually the group was enlarged and bifurcated into several smaller groups. One of the major groups among these started pioneering work on Defect Properties and Amorphous Materials and won recognition for the work. Other important areas of Solid State Research were : lattice dynamics, paraelectric defects in ionic crystals, thermal and electrical transport in semiconductors and semiconductors materials research. One of these groups has been working in active collaboration with a research group at the University of Wales. Among other major theoretical research groups were those on particle physics and quantum optics. These groups have several outstanding contributions to their credit.

The X-Ray, Ultrasonic, Spectroscopy and Microwave Laboratories in the Department of Physics are among the oldest research units and some of them have been equipped with modern high tech instruments. Some of the research facilities include high temperature graphite furnace with temperature reaching upto 3000C, computer controlled bridges for various kinds of electrical measurements, Rikagu X- Ray Unit to study XANES and EXAFS, X-band ESR Spectrometer with temperature variation accessory. The Department has a workshop which can be made more effective in the maintenance and repair of equipments.

PRESENT THEORETICAL RESEARCH AREAS: High Tc oxide superconductors, Fullerens, Alloys, Defects, Superlattices, Surfaces, Quantum confined systems, Nanocrystals, Paraelectric defects in crystals, Thermoelectric Materials, Quantum Optics and Non linear Optics, Nuclear Physics and Particle Physics, Plasma Physics, Chaotic Dynamics and Magnetohydrodynamics.

PRESENT EXPERIMENTAL RESEARCH AREAS : Microwave Dielectric properties, Optical Spectroscopy, X-Ray Spectroscopy, X-Ray Crystallography, Ultrasonic Studies, ESR, Liquid Crystals, Ceramics.

(List of the faculty members along with their research areas are presented in Appendix -I).

SUPERCOMPUTER LABORATORY: The Condensed Matter Physics group of Physics Department has an unique facility for performing very complex accurate numerical calculations on very fast supercomputer configurations. This lab includes the latest Hewlett- Packard machines like 4- node HP 735 CLUSTER, parallel processing computer, Double CPU K- 360 machine and various others.

MICROWAVE & MATERIALS LABORATORY: We have developed the following infrastructure for electrical, optical and phase transition studies under the COSIST and SAP programmes:

(i) Thermodynamical studies on Perkin-Elmer Differential Scanning Calorimeter (DSC-7).

(ii) 1 Hz to 100 Hz ferroelectric polarisation reversal switching experiment using a digitising CRO (HP 54200A) and computer interfacing.

(iii) Impedance spectroscopy from 100 Hz to 40 MHz on an RF impedance analyser (Hewlett-Packard 4194A) and temperature controlling interfaced by HP computer alongwith Julabo temperature controller (model F20).

(iv) Complex electrical permittivity and complex magnetic permeability on a microwave network analyser from 50 MHz to 26.5 GHz (HP 8510B) interfaced by HP computer (HP 300).

(v) Hot-stage polarisation measurements on polarising microscope (CENSICO) fitted with a Yashika FX camera.

(vi) We have recently purchased hot-stage (Instec HS1-i) alongwith Vintron PC (Pentium 120) for controlling temperatures from room temperature to 200°C with an accuracy of 0.003°C.

HONOURS AND AWARDS

The awards of Fellowships of Royal Society to two of the eminent members of the faculty marked the golden era of the research tradition in the Department. During recent past the faculty members of the department won several academic awards for their contributions. Professors Krishnaji was honoured with the prestigious *Raman Award*. Professor Krishnaji and Professor Vachaspati were selected National Professors by University Grants Commission. Professor Bipin Kumar Agrawal was elected Senior Associate of The International Centre for

Theoretical Physics, Trieste, Italy. Professor Vachaspati, Dr. Hari Prakash, Dr. Naresh Chandra were honoured with Dr. K. L. Bhal Award by U.P. State Literary Awards Committee. Professor Bal K. Agrawal was elected fellow of the Indian National Science Academy (FNA), National Academy of Science, India (FNASc.) for his outstanding contributions. Professor S. K. Kor was honoured with the *Bhagawantum Award* and was the President of Acoustical Society of India during 1984-86. Professor S. L. Srivastava has been elected Fellow of National academy of Sciences, India (FNASc.) and fellow of the institute of Electronics and Telecommunication Engineers. Professor C. M. Bhandari was a member of the International Advisory Committee of the First European Conference on Thermoelectrics. Several members of the faculty presided over sessions in International Conferences and Seminars. Dr. IML Das was awarded Young Scientist Fellowship by the International Union of Radio Sciences in 1987.

PUBLICATION OF BOOKS

Over the decades the faculty members in addition to their academic and research activities, published a number of books. A list of books published during last ten years is given in Appendix II.

TEACHING PROGRAMME

During the past few years there has been a determined efforts to improve and update the courses at both the undergraduate and postgraduate levels. Important steps in this context include:

I. A complete revision of course : *additional papers introduced.*

At the undergraduate level the entire course contents is to be evaluated through ten theory papers. There is equal weightage to course at all levels.

II. B.Sc. Part III : as part of the three year degree course.

This includes : (a) Four theory papers (out of ten mentioned above); (b) Compulsory project work in addition to the laboratory work. Over the years the laboratory has introduced a large numbers of useful experiments including those on electronics and laser.

III. At P. G. Level : entire course content is now evaluated through twelve papers (earlier eight). Inclusion of project work is on the cards. Student seminars are also being held.

IV. General Computer Facility: In addition to the computer facilities available with the various research groups, the department has general computer facility with an upcoming computer laboratory with a number of PC's including Pentium, three printers, and a plotter. Postgraduate students are being trained in basic programming.

V. Solid State Physics Laboratory: Keeping in pace with the Condensed Matter Physics Theory group making outstanding contributions for more than 40 years, a Solid State Physics laboratory has also been established recently in 1995. A special paper in M.Sc. (Final) has been started imparting training of quite modern and high level of the area.

VI. Non linear and Quantum Optics lab:° The lab is under installation and a new special paper on this subject likely to be initiated next year in M. Sc. (Final).

SEMINARS AND CONFERENCES : The Department has organized several seminars and conferences over the years. The department organized Raman Centenary Celebrations including a National Seminar in November 1989. In addition to a large number of papers on Raman spectroscopy, superconductivity and material research, the seminar was highlighted by an entire session devoted to the Future of Science Education and Research in India.

The department has organized Saha Centenary Celebrations in October 1993. A series of lectures were organized during the year. Among the eminent speakers were Professors. B.D. Nagchaudhury, Yashpal, Shantimay Chatterjee and Jayant Narlikar.

RESEARCH PUBLICATIONS : Several hundred research publications and review articles have been published in International Research Journals and Books (See Appendix III for list).

MISCELLANEOUS : Among other academic activities in the department are regular Thursday Colloquia and seminars. In this programme, lectures by faculty members and by visiting scientists are being organized for the past several years. These are aimed at exposing the faculty members, research and postgraduate students to the latest development in various fields, and to provide an opportunity for a free interaction among them.

The Physics Society celebrated its Silver Jubilee in 1987. A special issue of the Physics Society Bulletin was published on the occasion. Due to financial constraints it has not been possible to publish the Bulletin annually. The latest issue appeared in 1991-92. The Society from time to time, arranged lectures, seminars, debates and various competitions for the student members.

In January 1991 the "Children meet scientists" programme was held in the department. Sponsored by NCERT it was aimed at providing the young talented students from the local colleges an opportunity to interact freely with the faculty members. With about sixty participants the programme was a grand success. In June 1993 a summer school was held for the National Talents Scholarship awards. A comprehensive yet informal lecture-cum-laboratory programme was successfully organized by the department.

PHOTOGRAPHY SECTION

In 1938, a Certificate of Proficiency course in Photography was started by the University under the Physics Department. A Diploma course was added to the curriculum in 1940. The establishment of this job-oriented course was made possible due to the interest and efforts of some of the eminent professors of the Faculty of Science. Among them were Professor J.D.Tiwari, Professor Saligram Bhargava and Professor Mitra. Mention must also be made of the teachers who literally devoted their entire lives for the betterment and regular running of the Diploma and Certificate Courses Sri M.P.Gupta and Sri S.H.H. Razavi were among the teachers whose contribution shall always be remembered.

The University of Allahabad has recently started photography as one of the subjects at the undergraduate level in both arts and science disciplines.

RESEARCH ACTIVITIES OF PHYSICS DEPARTMENT

THEORETICAL

CONDENSED MATTER PHYSICS

1. Defect Properties and Alloys: Using Green's function theory, the group has predicted and understood the localized, resonance and gap modes and the various physical properties like the phonon conductivity, lattice specific heat and the infrared absorption by obtaining simple analytical expressions. For making comparison with the experimental data, t-matrix for realistic crystal structures have been derived and the crystal properties induced by the point defects or impurities have been extensively investigated. Some of them are frequency shifts and phonon widths, elastic constants, infrared absorption, Raman scattering, lattice specific heat. A new definition for effective force constant for impurity has been proposed. The work has well been reviewed in several books and articles.

2. Surface Soft Mode and Phase Transition : The theory group has investigated the effects of anharmonicity on the surface modes and the possibility of the soft phonon in rare gas monolayers deposited on graphite. The computed values of mean square displacements are in agreement with the experimental data. The group has also investigated the H-layer induced phonons on W(001) surface having different types of reconstructions.

A theory for the sticking coefficient has been given with the prediction that it will be different from unity only if the adaton surface coupling is quite weak. The theory explains the behaviour of the system near the transition state in a chemical reaction.

The group has explained the occurrence of streaks in the reflection high energy electron diffraction (RHEED) experiments.

3. Oxide Glasses: The theory group has propounded a new continuous random network theory for phonons in 2-4 coordinated glasses like SiO_2 , GeO_2 etc. after considering short range order in a generalized valence force field. The numerical results explain the infrared and Raman data.

4. Amorphous Semiconducting Alloys: Amorphous semiconductors are promising materials for development of cheap solar cells. A cluster Be the lattice method (CBLM) was developed and applied by the group for making extensive calculations for the study of elementary excitations such as electrons and phonons in amorphous semiconducting alloys. The systems investigated are a-Si:F(H), a- A_{1-x} B_x C, a-Ge:F(H), a-GaAs:F(H), a-Si_3 N_4 : H(D) and a-Si_{1-x} $(Ge,C)_x$:F(H). F and H atoms are used as passivators of dangling bonds in amorphous networks.The theory group has explained for the first time the available infrared and photoemission data in terms of occurrence of SiF(H) units. In a-A_{1-x} B_x C alloys a two phonon mode behaviour has been predicted in contrast to one mode behaviour suggested by other workers.

Shallow and deep electron levels produced by quantitative disorder, relaxed defects and impurity atoms have been predicted in a-Si and a-GaAs. Various kinds of defects like vacancies, wrong bonds, antisites, interstitials, and EL2 defects have been investigated by using CBLM.

5. High Tc- Superconductors: By employing LCAO method and a force constant lattice dynamical model, the group has explained the photoemmission, infrared and neutron data of the Tl-based oxide superconductors (hole excitations) and - Nd_{2-x} Ce_x Cu O_4 (electron excitations). The shift in Fermi level with x or y in $Nd_{2-x}Ce_xCuO_4$ (or $Nd_2CuO_{4-y}F_y$) observed in experiments have been explained for the first time.

6. Ab-initio Method: The group has employed a first- principles self-consistent full potential linear muffin tin orbital (LMTO) method with the density functional theory in the local density approximation. The method has been applied to study the structural, dynamical and electronic properties of different kinds of solids like semiconductors, high Tc oxide superconductors and doped fullerenes. The method has capabilty of predicting the various properties of solids quite accurately. Perfect as well as imperfect solids have been treated.

7. Anomalous Band Gap Bowing in Semiconducting Alloys:: The group has predicted an anomalous band gap bowing (red shift) in Nbased alloys like Ga (Al) As_{1-x} Nx. This behaviour has been observed in photoluminescence measurements in dilute GaAs:N alloys. These wide gap alloys have immense technological applications like blue light emitting devices and lasers.

8. Electron States of Semiconductor Surfaces: The group has predicted the electronic surface states of several semiconductors like (110) and (100) surfaces of GaAs, GaN, InAs, InP, SiC, GaP etc. The results for the dispersion curves are in excellent agreement with the photoemission data wherever available .

9. Quantum Wells or Superlattices: The results of ab-initio calculations obtained for different kinds of quantum confined systems of one dimension are in good agreement with the experiment.

The systems studied are ZnSe/ZnS(001) and (110), GaAs/GaN(001) and SiC/GaN(001) superlattices. The interface states have been predicted and so are the valence band offsets (VBO). The VBO's reveal strong sensitivity on the atomic relaxation in the vicinity of the interface or heterojunction.

10. High Tc-Oxide Superconductors: The ab-initio method has very successfully predicted the electronic structure of the recently discovered high Tc_oxide superconductors such as pure and doped parent superconductor $CaCuO_2$, Hg-based superconductors for whom the maximum value of Tc ($\sim 165^oK$ under pressure) has been measured. The occurrence of van Hove singularity(vHs) at different crystal volumes and its location with reference to Fermi level (E_f) have been investigated . The maximum value of Tc is expected to be achieved when vHs lies at E_f. The optimum values of the lattice constants or hydrostatic pressures for achieving highest values of Tc have been predicted. For example, the predicted value of pressure 25 GPa for Hg Ba_2 $CuO_{4+\delta}$ is in excellent agreement with the experimental results of several laboratories of the world.

11. Doped Fullerenes: The C_{60} A_x fullerens exhibiting superconductivity do not contain any CuO2 layer .The study of the electronic structure and vHs by the group predicts the occurrence of highest Tc at a lattice constant of 14.51Å for C_{60} K_3.

12. Quantum Dots or Nanocrystals: The ab-initio studied by the group reveal the enhancement of the fundamental gap with decrease in size of the zero-dimensional quantum-confined structure of Si , ZnS and others .The group is at present actively engaged in these investigations.

13. Semiconductor Transport and Thermoelectric Material research: A comprehensive study of thermal transportation semiconductors during sixties and seventies. Later on the electrical and thermoelectric properties were included in the studies. Also interested in material research programs with particular emphases in obtaining high performance materials for applications in thermoelectric generation and refrigeration. Active collaboration with the Thermoelectric Research Group at the University of Wales. The collaborative effort resulted in determining high performance materials based on silicon-germanium alloys. For low temperature application bismuth telluride based materials have been thoroughly investigated. Future extension to two-dimensional and one-dimensional systems.

14. Paraelectric Defects in Ionic Crystals : Theoretical investigation of paraelectric defects in alkali halide matrices (crystals). A recent achievement of the group is the development of two multiple tunneling model for adequately explaining a number of anomalous experimental results.

Further, ab initio calculations have been made of the potential barrier parameters for the NO^2 ion in alkali halide crystals; explanation of a number of experimental results. Other problems being investigated: study of electric field induced dichroism of OH in a number of alkali halide crystals, and development of microscopic theory for explaining the glass like behaviour of the $KBr^- CN^-$ system.

QUANTUM OPTICS & NONLINEAR OPTICS

1. Squeezing, antibunching, and other quantum features : We were the first (1969) to prove that antibunching and squeezing can be achieved experimentally in two photon resonant interaction of light with matter under certain conditions. We also show that light self-squeezes itself as it propagates in nonlinear medium having a third order polarization, and studied quantum features in several other nonlinear interactions. Recently, we show that the reduced statistics of amplitude and of phase can be classical or quantum separately for a quantum one mode field.

2. Density operator for unpolarized light : We show that the usual definition of unpolarized light is not adequate for nonlinear interactions. We gave new definitions and obtained the form of density operator for the unpolarized state.

3. Resonance Fluorescence and Quantum Beats : We studied fluorescence from an assembly of N-atoms. We showed frequency chirping and explained the results of Vrehen-Hickspoor-Gibbs experiment on quantum beats. We also studied Laser induced Rabi frequency quantum beats.

4. Polarized states of light and of fermions : We studied some hidden polarization states and also the reduced statistics of polarization. We obtained a polarization operator which helps to find if a given state represents perfectly polarized light and the polarization of this state. We also studied the polarized, unpolarized and spin isotropic states of fermions.

5. Free Electron Laser (FEL) : We calculated gain in FEL for fundamental and second harmonic, using the Feynman Dyson technique.We solved exactly the single particle dynamics problem in FEL. We are now studying the gain and the use of non-relativistic quantum theory to FEEL problems.

6. Representation of density operators of radiation : We gave some new representations and showed that one can get nonsingular weight functions in these unusual representations when the weight $P(\alpha)$ is singular.

7. Non-degenerate and degenerate parametric amplification : We studied these in great detail and several-quantum effects. One important result is conversion of random phase light into phase-coherent light.

8. Steady pulse propagation in resonant media : We showed that steady chirped π pulses and steady chirped asymmetric 2π pulses of arbitrary duration can exist in a lossy resonant inverted medium Solutions of Arecchi and Bonifacio and of Lamb for π pulses and of McCall and Hahn for 2π pulses are special cases of our more general results.

9. Nonlinear scattering of light by free and bound electrons : Second harmonic generation, frequency mixing, intensity-dependent frequency shift and natural frequency generation have been very extensively studied in Sixties and Seventies.

10. Non-linear Polarization and propagation of plane waves in a nonlinear Dielectric : We studied nonlinear polarization of dielectrics. We also studied how a polarization states change as pulse light waves propagate in a nonlinear dielectrics having third order nonlinear polarization.

11. Bosfer operators and States : We consider operators whose nonlinear expressions can give boson annihilation and creation operators which obey commutation relations, and also fermion annihilation and creation operators which obey anti commutation relations.

12. Other fields : Photo-pion production, coherence properties in diffracted light and in a nonlinear dielectric, higher order coherence functions, boundary conditions in electrodynamics, second harmonic generation in emission.

NUCLEAR PHYSICS AND PARTICLE PHYSICS: The group has been one of the major research groups during the sixties and the seventies. Present research programmes include: (1) Study of nuclear systems containing anti-nucleons, (2) Meson spectroscopy in Klein-Gordon equation using Quark model, (3) Radial distribution of quarks in a nucleon, (4) Photonic decays of pseudoscalar mesons with the admixture of gluonic matter, and (5) Accounting for hadronization in non-leptonic charmed meson decay. The long range part of the baryon-baryon interactions is well represented by conventional meson exchange models but quark degrees of freedom become apparent at short distances and affect the nuclear properties. We have used a hybrid quark model for baryon-baryon system with a quark shell model representing the short distance effect to understand the Nolen Schiffer anomaly in mirror hyper nuclie. The binding energy of the doubly strange $_{\Lambda\Lambda}\Xi$ hyper nuclie formed by (K^-, K^+) reactions for different nuclear targets as well as Ξ non mesic decay in nuclie is also being studied in the hybrid quark model. The spectrum of the B_c family of bc bound states in the framework of non-relativistic quantum mechanics is being computed. We intend to incorporate the phenomenological uses raised by the B_c family regarding the systematic of spin splitting for the unequal mass bc system and

the importance of relativistic $O(\beta^2)$ corrections.

CHAOS & FRACTALS:The following areas have been studied:-Mappings as Chaotic Dynamical Systems, Escape time in neighbourhood of Mandelbrot Set, Split bifurcation in a cubic mapping, Control of Chaos, Multifractals, Multifractal distribution of multiparticle production in High Energy Physics, Fractal Coding of Images, Scale Relativity and Fractal Structure of Quantum Space-time, Fractal Structure of the Universe, Secure communication using Synchronized Chaos, Synchronization in Coupled Chaotic Maps, Thermodynamics of Chaotic Systems.

SPACE PLASMA PHYSICS: Study of the generation, propogation and interaction of low-frequency electromagnetic(whistler) wave in the terrestrial ionosphere and magnetosphere including the effect of magnetic field aligned (parallel) to electric field. Application to explain the morphological features of several geophysical phenomena such as VLF chorus, hiss etc. Future extension to the whistler wave propagation in the planetary magnetosphere of Jupiter, Venus, and Saturn; comparative theory of planetary magnetospheres.

EXPERIMENTAL

NEW MATERIALS

1. Thermodynamic and Dielectric Studies of Cholesteric Liquid Crystal Mixtures : Liquid crystals are the class of materials, which have a large number of phases in a small span of temperature. We have been trying to understand the mechanisms of phase transitions of different thermotropic liquid crystal mixtures specially with the objective of inducing new transitions and also developing such a mixture which has a very wide range of cholesteric or nematic phase.

Transition temperatures, transition enthalpies and entropies of different mesophases of the binary mixture of cholesteryl pelargonate and nonyloxybenzoic acid have been measured on a differential scanning calorimeter and optical textures of different mesophases have been confirmed on a polarizing microscope. Eutectic point has been observed from the variation of transition temperature, enthalpy and entropy of the crystal to mixed crystal phase and the mixed crystal phase to mesophase with concentration of the acid. Stability of the SmA phase has been found to increase on addition of the acid. A new phase SmA* has been induced in between SmA and Ch phases.

Dielectric constant and electrical conductivity of the binary mixtures have been measured both in planar and homeotropic alignments for different concentrations. Dielectric constants parallel and perpendicular to helical axes and the dielectric anisotropy have been determined in different mesophases. Dielectric anisotropy of the mixtures changes sign from negative to a positive value above a particular concentration of the acid. From the measured frequency dependent conductivity, d.c. conductivity has been obtained using the universal power law equation. Activation energy of the d.c. conduction process has been determined in different mesophases.

2. Ferroelectric and Dielectric studies of Ferroelectric Liquid Crystal Mixtures : Ferroelectricity in liquid crystals has been a matter of study only during the last two decades or so. The planar oriented systems show collective modes only in the kHz region and are also electrically switchable. There are already a large number of applications of such devices.

Currently our objective is to study the hard twisting mixtures having small pitch of the order of 0.2 to 0.5 (m and a large spontaneous polarisation of the order of 100 to 300 nC/cm2.

Switching time, spontaneous polarization, torsional bulk viscosity and optical tilt angle in the SmC* phase and induced tilt angle in the SmA* phase produced by the electroclinic effect have been determined for a planar oriented FLC mixture. Knowing the induced tilt angle, the flexoelectric coupling constant and thermodynamic Landau parameter have been calculated.

Dielectric strength, relaxation frequency, Cole-Cole distribution parameter and dc conductivity for phason fluctuations in SmC* phase and amplitudon fluctuations in SmA* phase have been determined using an impedance analyser. Phason rotational viscosity, phason elastic constant and amplitudon rotational viscosity have also been calculated. For the soft mode in SmA* phase it is observed that dielectric strength, dielectric loss and the ratio of the static dielectric constant to the high frequency limiting dielectric constant follow the Curie-Weiss law. Activation energies of dc conduction processes and viscosities in both the mesophases have been determined.

3. Piezoelectric and Ferroelectric Ceramics : Piezoelectric and ferroelectric properties of lead zirconate titanate (PZT) ceramics though had been studied since long, yet the physics of these properties is yet not fully understood. Our experiments in this field have opened up the possibilities of understanding these properties. This work will be extended to nanocrystalline PZTs and also we aim to extend our measurements to microwave frequencies and develop some novel microwave ceramic materials.

Piezoelectric radial modes of Mn and Cr doped PZT ceramics have been measured on an Impedance Analyser. Effect of doping on the piezoelectric properties reveal interesting structural changes in the morphotropic phase boundaries of the ceramics. The overtones help us in determining the Poisson's ratio of the material. Coupling coefficient, elastic compliance, strain constant and voltage constant are found to be independent of the harmonics.

Ferroelectric to paraelectric phase transition studies have been carried out by the dielectric constant and dielectric loss measurements. A strong temperature dependent space charge effect has been observed on the dielectric constant and dielectric loss which have been corrected for by using a simple empirical model consistent with the Kramers-Kronig relations.

4. Dielectric Properties : The various thermodynamic parameters, free energy, enthalpy and entropy of activation as a rate process and the viscosity effect on molecules have been studied to get information about their group rotation and rotation of the molecules as a whole. Dielectric studies of liquids have provided information about their molecular structure and intermolecular forces.

Presently we are planning to develop ferromagnetic materials to provide low temperature coefficient and low loss with high dielectric constant for their large applications in microwave integrated circuits and microwave communications.

X-Ray SPECTROSCOPY

One of the oldest and renowned laboratories of the department with extensive work on satellite lines and crystallographic studies.

Recently acquired Rikagu X-ray unit will be used to study XANES and EXAFS of various substances to get valuable information regarding their electronic structure and inter atomic distances. The advantage of the method lies in the fact that crystalline and non-crystalline solids as well as biological specimens can be studied alike.

The group in X-ray laboratory has been particularly interested in studies concerning EXAFS and XANES in compound of gold, mercury and some super conducting compounds of Thallium. In collaboration with other laboratory (Prof. R. S. Saroda, Goa University), we have studied $Tl_2Ba_2CaCu_2O_7$, $Tl_{0.5}Pb_{0.5}Sr_2CaCu_2O_7$, $Tl_2Ba_2CaCu_2O_8$ and $Tl_2Ba_2Ca_2Cu_3O_{10}$ (all superconducting) and information about the nearest neighbor distance and their numbers have been estimated.

In another activity in collaboration with the Kamla Nehru Memorial Hospital, Allahabad we have established parameters for quality assurance of the whole body CT scanners in medial diagnostic practices. The CT scanners have been utilized for gamma radiation beam portal definition in radiotherapeutic applications. CT numbers have been converted in electron densities of the human tissues for application in cancer treatment. The work involved the utilization and development of comprehensive all-purpose CT phantom for performance evaluation of the CT scanner before its information could be utilized for clinical practices. The data will be utilized for Radiological Safety at the national level.

MOLECULAR SPECTROSCOPY

The vibrational spectra of transition and rare earth metal halides such as the monohalides of cobalt and nickel, and yttrium, alkaline earth chloride and certain transition metal Selenide halides have been investigated.

For determining the nature of the electronic states involved in the transition metal halides and Selenides suitable laser spectroscopic techniques are being planned. We have photographed the spectra of monohalides of nickel, cobalt, alkaline earth elements, yttrium and ytterbium, SnF, MnS, MnSe and Cu, using Carl Zeiss 2m Plane Grating Spectroscope PGS-2 at a dispersion of about 0.7 nm/mm and 0.35 nm/mm . These spectra yield new informations about their electronic structure and molecular constants. It has been noticed that the spectra of transition metal (Cobalt & Nickel) halides are complex in nature.

Laser facilities have been developed to study Laser Induced Fluorescence Opto galvanic Spectroscopy and Photoacoustic Spectroscopy for studying the halides of the transition and rare earth elements as well as some molecules which are found as pollutants in enviornment to find out absorption coefficients and absorption cross section with variation of pressure and composition.

Action 0.3m Monochromator with TE cooled ICCD with software etc., Spex 0.75m Monochromator with photon counting optics, Spectra Physics Nd-YAG Laser 1J with third harmonics optics, Laser Abelation Vacuum Chamber.

ULTRASONIC STUDIES

For Crystals like semiconductors (PbS, PbTe,SnTe), Alkaline Earth Oxides, mixed crystal systems, alloys etc. at different higher temperatures along no. of crystallographic directions

the second and third order elastic constants have been determined. Recently the studies of acoustical absorption in intermetallic compounds as $CeAl_3$ alloys at very low temperatures are made. Experemental measurements have been made in liquid crystals specially lyotropic liquid crystals. Charecterization of Viterous Silicon with reference to some electrical properties has been made.

In future it is being planned to establish laser ultrasonic material characterization unit to solve the problems at elevated temperatures and material surfaces.

EPR

The Cu^{2+} complexes with various amino acids and single crystals of Cu^{2+} doped in various diamagnetic lattices have been prepared. Their ESR, optical and Infrared absorption studies have been carried out to analyze the problem of splitting of different states in the field of varying symmetry and to interpret the strength and nature of bonding in the complex. Linewidth parameters have been used to interpret the mechanism of various magnetic as well as non-magnetic interactions. The magnetic strength of metal ion surrounded with different ligands have been estimated.

Appendix – I

FACULTY MEMBERS WITH THEIR SPECIALIZATIONS

THEORETICAL:

1.	Prof. B. K. Agrawal	High Tc Superconductors/Defects/Alloys/Surfaces/
2.	Dr. (Km.) Savitri Agrawal, (SSO-II)	Quantum confined systems/Superlattices/ Nanocrystals/ Transport properties
3.	Dr. B. K. Ghosh	Defects and Alloys
4.	Dr. P. S. Yadav	Defects, Alloys, Nanocrystals, Interfaces
5.	Prof. P. K. Sharma	Lattice Dynamics/Defects/Anharmonicity
6.	Prof. Hari Prakash	Quantum optics/Nonlinear optics
7.	Prof. Naresh Chandra	
8.	Dr. (Mrs.) R. Prakash	
9.	Prof. G. K. Pandey	Paraelectric Defects in Ionic crystals/Microwave Spectroscopy
10.	Prof. V. K. Jaiswal	Magnetism
11.	Prof. C. M. Bhandari	Transport properties and Thermoelectric Materials
12.	Prof. N. K. S. Gaur	
13.	Prof. (Mrs.) I. Mehrotra	Nuclear Physics and Particles Physics
14.	Prof. M. C. Sharma	
15.	Dr. (Mrs.) Chitra Dar	
16.	Dr. A. K. Mittal	Chaotic Dynamics
17.	Dr. IML Das	Plasma Physics
18.	Dr. A. C. Pandey	Magnetohydrodynamics

EXPERIMENTAL:

1.	Prof. S. L. Srivastava	Microwaves/ceramics/Liquids/crystals
2.	Prof. A. N. Vishnoi	Xrays Spectroscopy
3.	Prof. Vinod Prakash	Microwave Spectroscopy
4.	Prof. Pradeep Kumar	Microwave Dielectrics
5.	Prof. S. C. Srivastava	Microwave Dielectric
6.	Prof. V. K. Agrawal	Microwave Dielectric
7.	Dr. R. R. Yadav	Ultrasonics
8.	Dr. Ram Gopal	Optical Spectroscopy
9.	Dr. Ram Kripal	ESR/EPR
10.	Shri Himanshu Tiwari	Photography

APPENDIX-II

(Books and other publications)

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Quantum Mechanics & Field Theory, Bipin K Agrawal, Lokbharti Publications.
X-Ray Spectroscopy, Bipin K Agrawal, Springer Verlag.
Electric Circuits & Introduction to Electronics, Vinod Prakash, Lokbharti Publications.
Proceedings of the National Symposium on the Interface of Physics & Biological Science (Madurai), 1984, Ed. S L Srivastava
Proceedings of the National Seminar on Electronics for Teaching and Mass Education, New Delhi, 1986, ed. S L Srivastava
Thermal Conduction in Semiconductors, C M Bhandari & D M Rowe, Wiley Eastern Limited, 1989.
Nuclear Physics, Bipin K Agrawal, Lokbharti Publications.
Proceedings of the Symposium of Plasma Science and Technology, edited by I M L Das, Allied Publishers, 1994
Proceedings of the Symposium on Spectroscopy and Astrophysics, edited by A K Gupta, Kitab Mahal.
Nothing but All —An inquiry into the meaning and Implication of Modern Science, C M Bhandari, Kitab Mahal
Quantum Mechanics, Bipin K Agrawal and Hari Prakash, Prentice Hall of India, 1997
Saiddhantik Bhautiki (Hindi Translation of Konpaneyets, Theoretical Physics, Parts I and II), UP Hindi Grants Academy 1974, author- Vachaspati, Hari Prakash and Naresh Chandra.
Prayogik Bhautiki, Krishnaji and S. L. Srivastava.
Vidyut Chumbakatia Ke Sidhanta, Krishnaji and S. L. Srivastava, Hindi Granth Academy.

APPENDIX-III

LIST OF PUBLICATIONS (List is incomplete)

THEORETICAL

Condensed Matter Theory
Superconductors, Alloys, Superlattices
Review Articles Published in Books/ Monographs:

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5. B.K. Agrawal & S. Agrawal, van Hove singularity scenario in High Tc $HgBa_2$ $CaCu_2$ $O_{6+\delta}$ superconductors: Pressure effects, *High Temp. Superconductivity---* , 321- 324, 1997.
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Excerpts from a lecture
The Pursuit of Science : Its Motivations

Delivered by S Chandrasekhar at the Golden Jubilee of the Indian Academy of Sciences.

A conversation between Majorana and Fermi :

Majorana : There are scientists who happen only once in 500 years, like Archimides or Newton. And there are scientists who happen only once or twice in a century, like Einstein or Bohr.

Fermi : But where do I come in Majorana ?

Majorana : Be reasonable Enrico! I am not talking about you or me. I am talking about Einstein and Bohr.

****

There are some great men of science whose charm consists in having said the first word on a subject, in having introduced some new idea which has proved fruitful. There are others whose charm consists perhaps in having said the last word on the subject and who have reduced the subject to logical consistency and cleanness.

****

G.H. Hardy concludes his " A Mathematicians Apology" with the following statement :

The case for my life, then , or for anyone else who has been a mathematician in the same sense as I have been one is this : that I have added something to knowledge, and helped others to add more; and that these somethings have a value which differs in degree only, and not in kind, from that of the creations of the great mathematicians, or any of the other artists, great or small , who have left some kind of memorial behind them.

****

The pursuit of science has often been compared to the scaling of mountains, high and not so high. But who amongst us can hope, even in imagination, to scale the Everest and reach its summit when the sky is blue and the air is still; and in the stillness of the air survey the entire Himalayan range in the dazzling white of the snow stretching to infinity ! None of us can hope for a comparable vision of nature and of the universe around us. But there is nothing mean or lowly in standing in the valley below and awaiting the sun to rise over the Kanchenjunga.

SECTION 4

K. S. KRISHNAN Birth Centenary Conference on CONDENSED MATTER PHYSICS December 04-07, 1998

Scope of the Conference

Programme

Abstracts

Symbols

- *I : Invited Lectures*
- *O : Oral Presentation*
- *PO : Poster Session*

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Programme of Prof. K. S. Krishnan Conference on Condensed Matter Physics during Dec. 4-7,1998 at Physics Department, Allahabad University.

Dec. 04, 1998

Jointly Organized by Department of Physics, Allahabad University and The National Academy of Sciences, India, Allahabad.

08.30 - 09.45 A. M.	Breakfast/Registration in Physics Department	
10.00 - 11.00 Hours	**INAUGURAL SESSION**	
His Excellency, Chancellor	Sri Suraj Bhan	*Inaugural Inaugural Address*
	Dr. R. Ramanna	*Keynote address*
	Prof. N. K. S. Gaur	*Release of Souvenir*
11.30 - 12.00	***TEA***	
12.00 - 13.30	**SESSION - I**	
	Prof. S. Chandrasekhar, CLCR- *'Biaxial Nematic Liquid Crystals'*	
	Prof. C.K. Majumdar, SNBNCBS -*'Magnetic Properties of Solids'*	
13.30 - 14.30	***LUNCH***	
14.30 - 16.00	**SESSION - II**	
	Prof. R. Simon, IMSc. - *'Krishnan and the Sampling Theorem'*	
	Prof. Madan Rao, IMSc.- *'Non-equilibrium Structure in Solids'*	
16.00 - 16.15	***COFFEE***	
16.15 - 18.00	**SESSION - III**	
	Prof. G. Baskaran, IMSc. - *'High T_C Superconductors*	
	Prof. Deepak Dhar, TIFR- *'Self Organised Criticalities'*	
18.00 to 19.30	**CULTURAL PROGRAMME** *at Vigyan Parisad Hall*	
19.30 - 21.00	***DINNER***	

Dec. 05, 1998

Organized by Physics Department, Allahabad University

08.30 - 09.15 A. M.	***BREAKFAST***
09.30 - 11.30	**SESSION -IV Disorderd Systems & Alloys**
	Prof. Abhijit Mookerjee,SNBNCBS - *'Ist-Principles Study of Phase Stability in Alloys'* Prof. B. K. Agrawal, AU - *'Ist Principles Cal. of Defects & Alloys'* Prof. A. K. Bhatnagar, UH *'Disordered Metallic Systems'* Prof. K. N. Pathak, PU- *'Binary Collision Dynamics of Liquids'*
11.30 - 11.45	***TEA***
11.45 - 13.30	**SESSION -V Quantum Optics & Nonlinear Optics**
	Prof. K. C. Rustagi, CAT - *'Free Electron Optical Non-linearities'* Prof. Hari Prakash, AU 'Polarization States' Prof. Deepak Kumar, JNU *'Quantum Theory of Optical Interference'* Prof. R. R. Puri, BARC-*'N- spin-1/2 States Classical or Non-classical'*
13.30 - 14.30	***LUNCH***
14.30 - 16.30	SESSION -VI Experimental Techniques
	Prof. C. L. Khetrapal, AU - *'Revitalization of NMR of Oriented Systems'* Prof. M. A. Vishwamitra, IISc *'X-ray Diffraction of Biomolecules'* Dr. S. A. Ahmad, BARC- *'Laser Cooling of Atoms'* Dr. N. A. Narshimham, BARC - *'Role of Spectroscopy in Astrophysics'*
16.30 - 17.00	***COFFEE***
17.00 - 17.45	**EVENING LECTURE**
	Dr. R. Ramanna *'New Approach to Physics of Fundamental Particles'*
17.45 - 19.30	**Poster Session- I**
19.30 - 21.00	***DINNER***

Dec. 06, 1998

08.30 - 09.15 A. M.	***BREAKFAST***
09.30 - 11.30	**SESSION -VII Superlattices & Surfaces**
	Dr. S. K. Mehta, SSPL - *'Superlattices & Quantum wells'* Dr. G. P. Das, BARC -*'Ist Principle cal. of Interfaces'* Prof. A. P. Pathak, HU- *'Channeling in Superlattices'* Prof. B. K. Agrawal, AU- *'GaAs(SiC)/GaN Superlattices'* Prof. P. K. Basu, IRP- *'Quantum Wells'* Prof. Ramji Srivastava, VV- *'Semiconductor Interfaces'*
11.30 - 11.45	***TEA***
11.45 - 13.30	**SESSION -VIII Superconductivity & Nano-crystals**
	Prof. Y. Singh, BHU- *'Elastic constants of Liquid Crystals'* Prof. O. N. Srivastava, B.H.U. - *'Materials of 21st Century'* Dr. Uday Sinha, USA -*'Superconducting Cable'* Prof. S. H. Pawar, Shivaji Uni.- *'Photoinduced Superconductors'* Prof. K. N. Srivastava, UH- *'Fundamental Flux quantization'*
13.30 - 14.30	***LUNCH***
14.30 - 16.30	**SESSION -IX Nano Crystals & Ceramics**
	Dr. Alok. Jain, SSPL - *'Porous Silicon'* Dr. V. K. Jain, SSPL - *'Smart Structures of Si'* Prof. Vipin Srivastava, HU -*'Integer Quantum Hall Effect'* Prof. S. Basu, IITK- *'Laser Annealed Thin Films'* Prof. S. Lalitha Sardeshmukh, KU- *'Electrical Prop. of Doped YAG* Prof. V. A. Tabhane, Nagpur- *'Phase Transitions in Liquid Crystals'*
16.30 - 17.00	***COFFEE***
17.00 - 17.45	**EVENING LECTURE**
	Dr. Vikram Kumar, Director, SSPL
17.45 - 19.30	**Poster Session-II**
19.30 - 21.00	***DINNER***

Dec. 07, 1998

08.30 - 09.15 A. M.	***BREAKFAST***
09.30 - 11.30	**SESSION -X Quantum Hall Effect and Alloys**
	Prof. (Mrs.) Sumati Rao, MRI *'Fractional Quantum Effect'* Prof. S. L. Srivastava, AU -*'Piezoelectric & Ferroelect. properties'* Prof. S. C. Agrawal, IITK- *'Amorphous Silicon'* Dr. M. S. Roy, Jodhpur- *'Conduction Mechanism in Devices'* Miss. Arunima Mookerjee, AU- *'Ferroelectric Liquid Crystals'*
11.30 - 11.45	***TEA***
11.45 - 13.30	**SESSION -XI Magnetism & Superconductivity**
	Prof. C. M. Srivastava, IITB-*'Charge Carriers in High Tc Superconondductors'* Prof. S. Dattagupta, JNU - *'A Model Quantum Magnet'* Dr. S. K. Kakani, *'High Tc Cuprate Superconductors'*
13.30 - 14.30	***LUNCH***
14.30 - 16.00	**SESSION -XII Materials at High Pressure**
	Dr. S. K. Sikka, BARC- *'Studies of Equation of State'* Prof. Alok K. Gupta, AU- *'Study of pyrope-knorringite join'* Prof. A. Mansingh, DU *'Ferroelectric Films'*
16.00 - 17.00	**CONCLUDING SESSION**
17.00	***COFFEE***

J4-1

A Biaxial Nematic Liquid Crystal

S. Chandrasekhar

Liquid Crystal Research Institute, Bangalore

I shall describe recent calorimetric and optical studies carried out in our laboratory on the mosophases of the compound 1:4 (p-terphenyl) -bis [2, 3, 4-tri (dodecyloxy) benzaljimine. Differential scanning calorimetric curves reveal that there is a second, much weaker transition just below the usual isotropic- nematic point. Optical observations show that these transitions represent the isotropic-uniaxial nematic transition, and at a slightly lower temperature the uniaxial-biaxial nematic transition. Measurements are presented of the temperature variation of the biaxial angle in the biaxial nematic phase.

J4-2

Magnetic Properties of Solids : Krishnan's Contribution

C. K. Majumdar

S. N. Bose National Centre for Basic Sciences, Salt Lake, Calcutta-700 091

K. S. Krishnan and his students developed precise experimental methods to measure magnetic anisotropy of crystals. The work established the usefulness of magnetic methods as a valuab le supplement to the X-ray methods for determining crystal structure. This led the organization of the department of magnetism in the Indian Association for the Cultivation of Science.

Some remarks about the subsequent development in the field of magnetism will be made to put the work in modern perspective.

J4-3

Krishnan and the Sampling Theorem

Rajiah Simon

The Institute of Mathematical Science, CIT Campus, Tharamani, Chennai (Madras), Tamil Nadu-600 113, India

Krishnan loved mathematical reasoning and his skill as a mathematician would have gained him international recognition even without his great ability as an experimental physicist''—observed Lonsdale and Bhabha in their biographical notes on Krishnan. This talk is an attempt by one who has had no personal knowledge of Krishnan to understand and appreciate this curious remark on the {\em mathematics} of one of the greatest experimental physicists this country has ever seen. Such an effort can well be a losing game, for it is likely that the content and spirit of the above remark based on personal knowledge can never be fully grasped by just reading Krishnan's published works but one must try.

Anyone who scans through the littles of Krishnan's collected works is sure to notice one

piece of work that is singularly and manifestly different from the others every other work invoives a physical phenomenon, right from the title, whereas this one makes virtually no reference to physics. This work was published in 1948 when Krishnan was Director of the National Physics Laboratory, through a short note in Nature titled "A simple result in quadrature", followed by a detailed one in the Journal of the Indian Mathematical Society under the title 'On the equivalence of certain infinite series and the corresponding integrals'. The mathematical issue Krishnan pursues in this work arose during his study of a physical problem with Bhatia and this, if anything, is the only connection with physics. This should be the work Lonsdale and Bhabha were referring to when they continued their remark to say "Krishnan was deeply moved by a by-product of purely mathematical interest thrown up during the course of a physical investigation." This tribute to the memory of Krishnan on the occasion of his Birth Centenary is confined exclusively to the particular work of Krishnan.

Krishnan loved mathematics and those who knew him had great respect and even awe for his skill as a mathematician. However, he chose to publish in mathematics just once and for future generations this particular work of Krishnan remains just about the only source from which to gain a glimpse of his mathematics. 'This work is outlined and is shown that Krishnan's main result is essentially equivalent to the sampling theorem of Shannon that appeared a little later'. While conventional wisdom viewed the sampling theorem as a powerful engineering tool in signal processing Krishnan saw in his main result a rich source of deep mathematical identities.

J4-4

Non-equilibrium structure in solids

Madan Rao, IMSc, Chennai

J4-5

How Well Do We Understand High Temperature Superconductors ?

G. Baskaran

Institute of Mathematical Sciences, C.I.T. Campus, Madras-600 113

More than a decade ago high temperature cuprate superconductors were discovered by Bednorz and Muller. Following their lead a family of these compounds were synthesized with Tc that ranges from nearly zero to about 160 K. Great progress has also taken place experimentally in understanding various basic properties of these systems. In the theory front, the RVB theory of Anderson and collaborators which came up with a great promise has gone through marry challenges and tests. It seems to be the only viable theory that is compatible with a whole lot of experimental facts. However, a lot remains to be done to make it a theory that is quantitatively correct and even qualitatively correct in one issue.

I4-6

Self-organised Criticalities

Deepak Dhar

Department of Theoretical Physics, Tata Institute of Fundamental Research, Mumbai

Many natural systems such as mountain-landscapes , river networks, clouds, turbulent eddies show fractal structure. The theory of self-organized criticality explains this ubiquity of fractal forms in nature by recognizing that many slowly-driven non-equilibrium systems under their natural relaxational dynamics tend to steady states with long-ranged correlations in space and in time. Some simple models of sandpiles, forest-fires, earthquakes, and river networks will be described to illustrate the application of the isles to different systems.

I5-7

First Principles Study of Phase Stability in Alloys

Abhijit Mookerjee

S. N. Bose National Centre for Basic Sciences, Calcutta

The talk will report on recent efforts to predict phase stability in transition metal alloys from first principles approaches. Study of PdV, PdRh and Transition metal aluminides will be reported.

I5-8

Ab-initio Study of Defects and Alloys

Bal K. Agrawal, P. S. Yadav, Rekha Srivastava and Savitri Agrawal

Physics Department, Allahabad University, Allahabad-211 002, India

A full potential self-consistent linear muffin tin orbital in the local density approximation (LDA) has been employed to investigate the electronic structure of the various defects like EL2 and others and the semiconducting alloys. The studied systems are the fourteen ordered $GaAs_{1-x}N_x$ alloys with x = 0.0, 0.037, 0.074, 0.111, 0.125, 0.25, 0.375, 0.407, 0.50, 0.625, 0.75, 0.875, 0.963, 1.0 and nine $AlAs_{1-x}N_x$ alloys with x = 0.0, 0.125, 0.25, 0.375, 0.50, 0.625, 0.75, 0.875, 1.0. The lattice parameter is seen to have a non- linear variation with the concentration of the constituent atoms. In $GaAs_{1-x}N_x$ alloys, a nearly closure of the fundamental energy gap appears in the concentration range 12.5% to 62.5% of N-atoms. A strong hybridization of N-s states with the Ga (s, p) and As- (s.p.) states is seen at the bottom of the conduction band and these states descend into the fundamental gap filling it either partially or completely. In $AlAs_{1-x}N_x$ alloys quite smaller gap appears in the neighbourhood of x = 0.125 concentration of N-atoms. The state lying at the CBM, which is composed of N-s, Al (s.p.), As-s descends into the fundamental gap filling it partially. The band gap for the random alloys also shows an anomalous bowing.

J5-9

Transport Properties of Highly Disordered Metallic systems

A. K. Bhatnagar

School of Physics, University of Hyderabad, Hyderabad

The conventional Boltzmann theory of electronic transport phenomena is expected to breakdown when the electronic mean free path in a metal becomes of the order of the lattice spacing and new effects can be expected. This talk will present experimental results of transport properties of a wide variety of highly disordered metallic systems and discuss the results in light of current theoretical ideas available to describe such results. The emphasis will be on resistivity, thermopower and Hall effect results on a number of systems. The thermopower is found to be enhanced at low temperatures in such systems because of electron-phonon interaction. In some transition metal containing systems, Hall coefficient is found to be positive which is believed to arise from anomalous dispersion of the conduction electron because of s-d hybridization. The temperature and magnetic field dependence of resistivity of such systems exhibit anomalies in comparison with that of "normal metals".

J5-10

Binary Cluster Dynamics of Fluids

K. N. Pathak

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The current studies of the dynamical and transport properties of liquids and dense gases are through the time correlation functions (TCF). The theoretical problem in the study of TCF is basically that of describing the atomic motions in many body system. The time evolution of TCF is generally studied by expressing it in terms of the memory function (MF) through Mori-Zwangig equation of motion. The MF contains in it all, the free streaming, uncorrelated, correlated binary and multiparticle cluster contributions. In this paper we present the evaluation of only the binary cluster contributions to the MFs of the velocity, longitudinal and transverse current auto correlation functions. These expressions involve the equilibrium average over the initial positions and moments for the trajectories of a particle moving in a central potential. The expressions are numerically calculable for any continuous potential. Further, our expressions in the limit of hard sphere interaction for $q \rightarrow 0$ provide results for the coefficients of self diffusion, shear, bulk, and longitudinal viscosities in agreement with Enskog results. The numerical results for the TCFs are also presented for Lennard- Jones fluids for various densities and temperatures and are compared with MD data where available.

I5-11

Free Electron Optical Nonlinearities

Kailash Rustagi

Centre for Advanced Technology, Indore-452013, India

In many interesting and practically important nonlinear optical materials, a "free electron" description provides a very useful starting point. Some of the examples include metal surfaces and nanoparticles mobile electrons in 3-5 semiconductors, pi electrons in organic dyes and fullerenes. Several important theoretical predictions made by such models have been experimentally verified. Our work over the years is reviewed. Also discussed are nonlinearities associated with plasmons in metal nanostructures and doped semiconductor quantum wells. We show that these materials are good candidates for observing intrinsic bistabilities.

I5-12

Polarization States

Hari Prakash

Physics Department, Allahabad University, Allahabad-211 002

A general discussion of polarization is done. Polarization operator, hidden polarization states, reduced statistics of polarization and change in polarization in a non-linear isotropic Kerr medium are discussed. Polarized, unpolarized and spin- isotropic fermion states are also discussed.

I5-13

Quantum Theory of Optical Interference

Deepak Kumar

Jawaharlal Nehru University, New Delhi

I5-14

N Spin-$^1/_2$ States : Classical or Non-classical

R. R. Puri*[1]

Bhabha Atomic Research Centre, Mumbai-400 085

The question of identifying the signatures of quantum effects has occupied the focus of attention since the birth of quantum mechanics. The necessary conditions for identifying such signatures in a system of a harmonic oscillator is well-known in terms of the Sudarshan-Glauber P-function. However, the signature of quantum effects in a system of two spin-1/2s are usually identified by means of the violation of the Bell type inequalities or the GHZ equalities for a system of three spin-1/2s. These violations provide sufficient but not necessary conditions for identifying the quantum nature of correlations between two or three spin-1/2 systems. The reason for that is of course, that those correlations can not define completely the distribution

1. R. R. Puri, J. Phys. (\bf 29) 5719 (1996)

function for spins. A necessary condition has to be formulated in such a way that it reflects the nature of the complete distribution function. In this talk, the issue of formulating a necessary condition for identifying the quantum nature of the correlations between an arbitrary number of spin-1/2 systems will be addressed. It will be shown that the phase space distribution functions for the spins are inadequate for formulating the said condition. Based on the concept of joint quasiprobability of the eigenstates of non-commuting components of a spin, a recently proposed criterion[1] to characterize the states of a system of N spin-1/2s as classical or non-classical will be discussed. That criterion characterizes any state of a spin-1/2 and a factorizable state of N spin-1/2s classical. It correctly identifies any pure entangled state of two spin-1/2s, an entangled eigenstate of any component of exchange symmetric spin system and squeezed spin states as non-classical.

J5-15

Revitalization of NMR of Oriented Systems

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NMR Spectroscopy of oriented systems provides the only available method for the precise determination of molecular geometries in the liquid state. Due to rapid increase of the spectral complexity with the increase of the number of interacting nuclei, the use of the technique has been restricted to the study of rather small molecules so far. However, recent advances in the field such as the discovery of liquid crystals with low order parameters, the use of high magnetic fields for orienting the molecules and the possibility of obtaining the deuterium spectra in the natural abundance of deuterium have revitalized the field. Such developments promise a bright future for this method to study more complex systems such as bio-molecules. These aspects will be discussed with emphasis on both the National and the International efforts in this direction.

J5-16

Single Crystal X-Ray Diffraction and Application to Biological Structures

M. A. Viswamitra

Department of Physics, Indian Institute of Science, Bangalore-560 012

X-ray analysis has now established itself, as a method capable of solving the most complex of molecular structures, if well ordered and diffracting crystals could be grown. In recent years, there has been a dramatic increase in the number of protein and DNA structures solved. In trying to understand their biological function it is essential to know the detailed crystal structures of these molecules. In many cases, from crystal structures have emerged ideas of how to modify and improve the function. The structural information can be much more than of biological interest. Crystal structures have now become an essential component of efforts in the rational design of novel drugs and molecules. An outline of the principle of a single crystal diffraction approach and some crystal structures in relation to our current interest in oligonucleotides and high temperature stable enzymes will be presented.

IS-17

Laser Cooling and Trapping of Neutral Atoms

S. A. Ahmad

Spectroscopy Division, Bhabha Atomic Research Centre, Mumbai-400 085.

Laser cooling and trapping of neutral atoms is presently a very active of research encompassing a wide spectrum of problems in physics[1]. Last two decades have seen a flurry of activities demonstrating new ways to use laser light to manipulate and to control the external degrees of freedom (the positions and velocities) of neutral atoms. Atoms have been cooled now to ultracold temperatures which can be confined in atom traps. At these temperatures, atoms behave as waves, either individual ones as in atom optics, or collective ones in Bose-Einstein condensation or in atom lasers.

We have undertaken a major programme of laser cooling and trapping of atoms in BARC. The objectives of the programme are three fold : ultra-high resolution spectroscopy of fundamental physics experiments, collective behaviour of fundamental quantum systems (Bose-Einstein condensation, Fermi liquid etc.) and atom optics. Magneto-optic trap (MOT) which works on the spontaneous radiation force in an inhomogenous magnetic field is the vital component in laser cooling experiments. Our work in this area is progressing[2] and hopefully soon we will be in a position to present some results.

IS-18

Role of Spectroscopy for an Understanding of Astrophysics

N. A. Narasimham, F.N.A.

Former Head of Spectroscopy Group, Bhabha Atomic Research Centre, Bombay, INSA Senior Scientist, Indian Institute of Astrophysics, Bangalore, India

Laboratory studies of the spectra of atoms and molecules enable their identification in astronomical sources. Conversely unidentified spectra observed first in stellar and planetary atmospheres, comets nebulae and interstellar space provide an incentive to obtain such species under laboratory conditions. Thus there is an intimate interplay between spectroscopy and astronomy. Some of the highlights of such studies will be presented.

IS-19

New Approach to Physics of Fundamental Particles

R. Ramanna

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1. B. N. Jagatap and S. A. Ahmad, Physics News, 28, 83 (1997).
2. B. N. Jagatap, K. G. Manohar, S. G. Nakhate, A. P. Marathe and S. A. Ahmad -being published in Current Science (1998)

J6-20

Growth of Quantum Well Structures By Molecular Beam Epitaxy

S. K. Mehta, R. Muralidharan, T. Srinivasan, B. P. Jain and R. K. Jain

Solidstate Physics Laboratory, Lucknow Rd. Timarpur, Delhi-110 054

Quantum wells are the building blocks of the recent electronic and optoelectronic devices such as high electron mobility transistors, quantum well laser and multi-quantum well photodetector. These devices consist of quantum wells of GaAs/GaAlAs and GaAs/GaInAs and other III-V materials. In this paper the growth characterization and application aspects of these quantum wells and their devices will be discussed. The growth for the quantum wells was done by molecular beam epitaxy and they were characterized by SIMS, SEM and PL etc. for their structural and optical properties. The role of quantum wells and superlattice in HEMTs, SQWSCH laser and QWIP will be discussed.

J6-21

First-Principles Calculations of Epitaxial Interfaces and Multilayers

G. P. Das

Bhabha Atomic Research Centre, Mumbai, India

Recent advances in the techniques of epitaxial growth have made it possible to achieve atomically abrupt intimate interfaces and multilayers which have wide ranging applications in materials science and device physics. A microscopic understanding of the interface electronic structure is essential to explain as well as predict various novel properties, such as the giant magnetoresistance (GMR), that have been observed experimentally. In this talk, I shall describe how first-principles local density calculations, based on supercell approach, can be used to investigate a variety of interface specific properties. The results on some prototype nearly lattice-matched systems involving metals, semiconductors and ceramics will be discussed.

J6-22

Ion Channeling in Strained Layer Super Lattices

Anand P. Pathak

School of Physics, University of Hyderabad, Central University, Hyderabad-500 046

The strained layer super lattices are formed for small thicknesses of III-IV compounds like Ga As with small amounts of In added in the alternating layers. The small lattice mismatched multi layers thus formed have small amounts of strain in the layers which can be studied using the ion channeling technique. The strains relax into extended defects for larger thicknesses and the effects of these defects are qualitatively different from those of the strains. We have studied these effects theoretically and recently experimentally also. The recent results of this study will be presented in this talk.

J6-23

Materials of 21st Century

O. N. Srivastava

Banaras Hindu University *see p.171*

J6-24

Luminescence from Porous Silicon

Alok Jain and V. K. Jain

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The observation of visible photoluminescence (PL) from porous silicon has attracted a great deal of attention. The material seems to be a big building block for optoelectronic devices. The observation of PL at room temperature is still not understood completely. It is very important to understand the role of surface states in PL. Our measurements of electroassisted photoluminescence and effect of different chemicals are quite helpful in the understanding of this phenomenon. It indicates that surface states created in the energy gap are responsible for the visible photoluminescence.

J6-25

Smart Structures of Silicon

V. K. Jain

Solid State Physics Laboratory, Lucknow Road, Timarpur, Delhi

The era in which, we are entering is of smart structures. It is a miniaturised system consists of sensors, intelligent electronics and actuators all integrated at one place. Such devices also go under various names such as smart materials, smart structures, MEMS, MST, (Micro System Technology) etc. These devices find wide applications in medicine, aerospace, automotive, transport, defence systems and other fields. These devices are non- biological systems but analogous to biological pattern of functioning. The complex MEMS devices can sense external events, analyse them to electronic circuitry and respond appropriately with minimum intervention.

Examples of such devices include self-repairing tyres, self- healing bridges, pressure sensors, gyros, accelerometers, night vision devices, catheters, micro motors and pumps. Microrobotics is another area which is getting more importance. These systems have recently been used on Pathfinder which landed on Mars.

Silicon is now poised to bring about another revolution as the base material for micromechanical devices. Although it is very difficult to machine silicon to make micron size device by traditional cutting tools, but it can be chemically etched into various shapes. The electrical properties of silicon are sensitive to stress, temperature and other environmental factors which means that silicon sensors can easily communicate with electronic circuitry for data processing.

J6-26

Piezoelectric and Ferroelectric Properties of Stabilized Lead Zirconate Titanate (PZT) Ceramics

S. L. Srivastava, V. K. Katiyar and Janardan Singh*

Physics Department, Allahabad University, Allahabad-211 002
**National Physics Laboratory, New Delhi*

Piezoelectric properties of poled chromium and manganese lead zirconate titanate (PZT) ceramics have been measured from room temperature to the Curie temperature region. Piezoelectric parameters of the radial mode excitations depend weakly on the temperature upto 250°C, above which the piezoelectric response becomes too weak to be analysed.

Dielectric constant and dielectric loss of the poled samples have also been measured scanning the temperature region from the ferroelectric phase to the paraelectric phase and sweeping the frequency from 10 Hz to 1MHz. At temperatures above 200°C there is a strong effect of the space charge on the electric permittivity. By making suitable corrections for the space charge effect, the dielectric constants of the ceramics obey the Curie-Weiss law and the complex electric permittivity over the space charge limited frequency region follows the Kramers-Kronig relation.

J6-27

Semiconductor Technology for the Next Decade

Vikram Kumar,

S.S.P.L., Delhi

Semiconductors are the main vehicle on which modern civilization is driving. The progress in all spheres of human activity—be it defence, communications, computers, space, entertainment, medical diagnostics or anything else—determined by the progress in semiconductor materials and device technology. There has been rapid progress in all directions in the last decade and we expect more in the next.

The VLSI technology is expected to yield 1 GHz computers. Band gap engineering will lead to higher frequency operations for microwave amplifiers. Gallium nitride based devices will provide higher power capabilities. Silicon will revolutionize mechanics the way it change electronics a few decades back. In this talk we will briefly review some of the trends in the semiconductor technologies.

J7-28

Fractional Quantum Hall Effect

Sumati Rao

Mehta Research Institute, Jhusi, Allahabad

We give a brief introduction to the phenomenon of the Fractional Quantum Hall effect and explain how the composite fermion picture gives a unified theory for all the filling fractions. We also discuss recent results on double layer FQHE and on edge states in the FQHE.

I6-29

The Integer Quantum Hall Effect : A Crux

Vipin Srivastava

School of Physics, University of Hyderabad, Hyderabad-500 046

That extended states must be present in a disordered two-dimensional electron system in the integer quantum Hall effect (IQHE) setting in order to carry Hall current came as a surprise in view of the common knowledge that a disordered 2 system should contain only localized states. Though the extended states are attributed to the presence of magnetic field (B) the question that has been most elusive is how do the extended states disappear in the limit B = 0 ? We have addressed this question here by introducing an alternative manifestation of the IQHE and suggesting an experiment to observe it. The results of the ongoing experiment are also reported.

The presented approach also offers some fresh insight into the spectacular phenomenon of the IQHE besides providing a very simple way of understanding it.

I7-30

Amorphous Silicon

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*Work supported by DST and CSIR, New Delhi

Hydrogenated amorphous silicon (a-Si:H) has a low enough density of localized states in the gap, so that it can doped n or p type at will by adding amount of impurities. This makes it suitable for making devices. Since a-Si:H is in the form of thin films and the energy required for its production is relatively small, it has emerged as a promising material for inexpensive large area devices, e.g., solar-cells, flat panel displays etc. Such applications have however, had only limited success, as a-Si:H based devices degrade upon use. Attempts to overcome these difficulties are hampered by the fact that the underlying physics involved in such phenomenon remains far from clear. This is because a-Si:H is a heterogeneous material in which hydrogen is distributed nonuniformly, in clusters. This gives rise to potential fluctuations, which are difficult to deal with in a fundamental manner, theoretically as well as experimentally. In this paper, we describe how transport and optical measurements can provide information about potential fluctuations in a-Si:H.

We show that optical absorption probes the short range potential fluctuations, whereas the electronic transport measurements are sensitive only to the long range potential fluctuations. Further, we find that light soaking (Staebler-Wronski Effect) increases the long range potential fluctuations whereas thermal quenching has hardly any effect on them. Implications of these results on the possible ways of reducing the metastabilities in a-Si:H, will be discussed.

J7-31

Nature of Charge Carriers and Its Implications for the Pairing Potential in High-Tc Superconducting Materials

C. M. Srivastava

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It has been proposed by us that the perplexing normal state properties of copper oxide superconductors arise from the polaronic nature of the charge carriers.[1] The momentum, temperature and doping dependence of photoemission spectroscopy and femtosecond optical absorption studies of nonequilibrium electronic processes in the normal and superconducting phases support this view.[2] Direct experimental evidence for polaronic charge carriers in La2-xSrxCuO4 has been provided recently by Zhao *et. al.* [3] The implications of the polaronic nature of the charge carriers on the pairing potential which has several features different from that of the conventional superconductors will be examined.

J7-32

Relaxation Processes in a Quantum Magnet

Sushanta Dattagupta

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The focus of this talk is the dipolar coupled Ising magnet LiHo(1-x)Y(x)F(4), in a magnetic field transverse to the Ising axis. When x is zero, the system is a model quantum magnet, which exhibits a quantum phase transition at zero temperature. We will show how mean field theory works very well in accounting for static and relaxation behaviour of the system. The analysis will be based on a quantum master equation for the density operator in a system-plus-reservoir approach. When x is non-zero, the non-magnetic yttrium ions induce disorder in the interaction between the magnetic holmium ions. In particular, for $x = 0.167$, and in zero transverse field, the system is known to be an Ising spin glass. Thus, the application of a transverse field makes the system a prototype "Quantum Glass", which is characterized by disorder as well as quantum fluctuations. We shall present a treatment of the frequent-dependent susceptibility of this system and compare results with experiments.

J7-33

Density-functional Theory of Elastic Constants of Liquid Crystals

Yashwant Singh

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We describe a density-functional theory based on weighted density fomalism to describe the elastic constants of liquid crystals. The expressions for uniaxial and biaxial nematics,

1. C. M. Srivastava, Physica C176, 481 (1991)
2. C. M. Srivastava, Pramana—J. of Physics, 50, 11 (1998).
3. Geo-meng Zhao *et. al.*, Nature (London) 385, 386 (1997)

smectics -A and -C phases are given. These expressions involve order parameters characterizing the nature and amount of ordering and the structural parameters which involve the spherical harmonic coefficients of the direct correlation function of an effective isotropic fluid the density of which is determined using a criterion of the weighted-density functional formalism. We discuss results found for some of these phases.

J7-34

Studies of Equation of State

S. K. Sikka

Bhabha Atomic Research Centre, Bombay

J7-35

Experimental Study on the System $MgSiO_3$-Al_2O_3-Cr_2O_3 Between 40 and 60 kbar at Different Temperatures with Special Reference to Pyrope-Knorringite Join

Alok K. Gupta

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Phase equilibria study of the pyrope-knorringite join, which is a part of the $MgSiO_3$-Al_2O_3-Cr_2O_3 system has been made between 40 to 60 kbar and 1300 to 1500°C. The subsolidus assemblages in this join are as follows : 1) $garnet_u$, 2) $garnet_u$ + $orthoenstatite_u$ + $corundum_u$ and 3) $orthoenstatite_u$ + $corundum_u$. Spinel and quartz do not appear in this join in the same P-T range, as claimed by some investigators (Irifune and Hariya, 1983 and Irifune, 1985). Present data rather confirm the observation of Malinovaki *et. al.*, 1975 and Turkin *et. al.*, (1982). The solubility of knorringite in pyrope increases with pressure and is 50 mole% at 60 kbar and 1500°C. Such garnets have chemistry similar to natural chrome-pyropes found as inclusions within natural diamonds or within kimberlitic xenoliths. The maximum knorringite content in such natural pyropes has been reported to be 50 mole%, suggesting the P-T condition of equilibration of such garnets at a depth of 180-200 km.

Reaction of following phases crystallizing in the same system, $MgSiO_3$-Al_2O_3-Cr_2O_3 was considered :

$$\underset{\text{(pyrope)}}{Mg_3Al_2Si_3O_{12}} + \underset{\text{(eskolaite)}}{Cr_2O_3} \leftrightarrow \underset{\text{(knorringite)}}{Mg_3Cr_2Si_3O_{12}} + \underset{\text{(corundum)}}{Al_2O_3}$$

Microprobe analyses of all the phases participating in the above reaction helped to determine activities of various components. These values together with the thermodynamic properties of pure pyrope, eskolaite and corundum helped to determine the standard entropy and enthalpy of formation of knorringite, which are as follows :

H_f^o (kJ/mol)	S_f^o (J/mol)	G_f^o (kJ/mol)
-5573.957	310.255	-5666.460

The topology of the solvus for the join Al_2O_3-Cr_2O_3 has been established at 60 kbar. The critical composition (X_c) and critical temperature (T_c) for the solvus have been determined at 60 kbar, and are found to be $Cor_{55}Eak_{45}$ and 1063°C, respectively. The assemblages across the boundary have been bracketed.

J7-36

Ferroelectric Films

A. Mansingh

Delhi University

Q6-0

First-Principles Calculation of Valence Band Offset and the Interface States in GaAs(SiC)/GaN (001) Superlattices

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A first principles scalar relativistic version of full potential self consistent linear muffin tin orbital (LMTO) method together with a local density functional theory has been employed for calculating the electronic structure of the superlattices formed from the two different types of semiconductors. In particular, we report the results for the lattice mismatched GaAs/GaN (001) and SiC/GaN (001) superlattices. The calculation has been performed for the two strain modes (i) free standing interface, where both GaAs and GaN are strained and (ii) GaN (strained) deposited on the unstrained GaAs. The calculated band offsets reveal strong sensitivity on the atomic positions in the interfacial region. The valence band offset increases (decreases) with decrease (increase) in the GaN (GaAs) bond length. There appear a number of interface states of localized and resonance types which may be responsible for the sensitivity of the band offsets on the atomic positions. The calculated band offset ranging from 1.4eV to 1.87eV for the GaAs substrate and the free standing geometries respectively is quite close to the experimental value of about 1.7-1.8eV reported by Ding *at. al.*, Band offsets have been predicted for SiC/GaN (001) superlattices which need experimental verification.

Q6-1

Si Based Optoelectronics : Feasibility Study of Unipolar Laser Action in Si Quantum Wells

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Although Si is the most widely used material for electronics, since in recent years, optoelectronics or photonics are considered to replace conventional electronics in the area of transmission processing and retrieval of information, its use as its indirect band gap makes it a very poor emitter of light. However photodetectors, especially Quantum Well Infrared

Photodetectors. Optoelectronic Integrated circuits based on Si/SiO2 and Si/SiGe heterojunctions and Quantum Wells (QWs), IR modulators and elements for optical networking are being fabricated using mature Si technology and Si Optical Bench (SiOB) is a widely used system today.[1]

In the emission side, possibility of creating quasi direct gap by zone-folding in Si/SiGe superlattice is still not bright. Er doped Si or SiGe LEDs, porous Si, Si Quantum Dot arrays, Si-Organics are being investigated for having efficient light emission.[2]

It occurs to us that inter-conduction subband transition in Si/SiGe QWs may be exploited for achieving unipolar laser action[3] around 5-50 μm wavelength range, as the dominant scattering by f-phonons is less frequent due to inherent strain[4] making non-radiative downward intersubband transition less probable. The transition is purely electronic, and not electron-hole recombination; hence the name unipolar.

In this paper, we review briefly the current status of Si- optoelectronics, but emphasize on the feasibility of unipolar laser action in Si QWs. The structures, various transition rates and the estimate of threshold current density are presented for different QW and tunneling barrier widths.

Q6-2

Semiconductor Interfaces

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Interfaces have always played a key role in influency behaviours. Semiconducting materials are no exception to this. In fact modern exploits in the field of electronics are based on this fact.

Out of various kinds of semiconductor interfaces which have been utilised for fabricating electronic devices metal semiconductor hetro interfaces are the one which have been utilised in a number of practical devices though its physics is still ellusive in this paper we discuss such interfaces as investigated by us using liquid metals. It is shown that much physical understanding can be expected with the mode of investigations discussed overhere. In this context results obtained on interfaces of mercury and gallium on silicon will be discussed. The results show diminishing role of interface zone in Fermi level pinning and explicitely shows the role of interfacial strain in the band line up at the interface.

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2. P. K. Basu, *Theory of Optical Processes in Semiconductors : Bulk and Microstructures.* Oxford University Press, Oxford, U.K. (1997)
3. J. Faist *et. al.*, Electronics Lett., vol. 30, p. 865 (1994)
4. P. K. Basu and S. Paul, J. Appl. Phys., vol. 71, p. 3617 (1992)

Q6-3

Test Results of Southwire's Short High Temperature Superconducting (HTS) Cables Prototypes and Plans for a 30-M Demonstration Cable

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Southwire Company, Carrollton, Georgia, USA

Nine 1-m and one 5-m high temperature superconducting (HTS) cables have been constructed by Southwire Company and tested at Oak Ridge National Laboratory (ORNL). Cables were designed with various design parameters to study the Ic of the cable, ac loss and other features. The 5-m cable is designed as a coaxial cable with two layers of HTS tapes separated by dielectric insulation. A suitable dielectric was developed to withstand high voltage at liquid nitrogen temperature. A test facility has been designed and assembled at ORNL with termination's and cryogenics cooling to test 5-m cables. Southwire plans to construct a 3-phase 30-m cable which will be installed between two overhead lines bringing power to Southwire's three manufacturing plants. The HTS cable will be designed to carry 1250 amps at 12.5 KV to match with the overhead power supply. The 5-m cable has been constructed to test the design features of 30-m cable. In this paper, the test results of short cable tests and installation plans for 30-m cable will be discussed.

Q6-4

Photoinduced Effects in High T_c Superconductors

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Since the discovery of high Tc superconductors in 1986, a number of families of compounds showing Tc values ranging from 30 K to 153 K have been reported in literature. Incidentally all these materials are black in colour. Their absorption and reflection spectra are found to differ from family to family and there are some discrete bands observed. In addition, the intensity of these bands are found to change with temperature. At the critical temperature, the band intensities are found to change drastically. The effect of light excitation on the Tc values of Y_1 Ba_2 Cu_3O_7-(have been studied and discussed in detail. The theoretical model has been proposed for the rise in Tc with photoexcitation for YBCO system.

Q6-5

Fundamental Flux Quantization

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Flux is known to be quantized in units of hc/2e where h is the Plank's constant, c is the velocity of light and e is the charge of the electron. The present day quantum mechanical theories allow (hc/2e) (n + 1/2) which makes half of the value as the smallest flux quantum. Whenever one mentions fractions of something assumed to be a fundamental constant, there

must be a new theory. In the case of paramagnetic Meissner effect, we find that 1/4 of the flux quantum occurs. The magnetization shows oscillations as a function of magnetic field where more oscillations are found than is predicted by rational fractions. In a matrix of wires containing Josephson junctions below a temperature of 0.3 K, the resistivity as a function of flux clearly shows that fractional flux occurs. The values of 1/2, 2/5, 1/3 and 1/4 are clearly seen. Arguments have been put to support that elementary flux is hc/2e but other values have not been contradicted. We have found that the imaginary part of the susceptibility oscillates as a function of magnetic field. The oscillations show that flux is quantized. Therefore, it may be concluded that not only pairs of electrons with charge 2e are responsible for superconductivity but quasiparticles of charge is,. 5e 6e and 8e are also needed.

Q6-6

Studies on Laser Annealed β-$FeSi_2$ Thin Films

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Silicides belong to a very important group of compounds which are particularly useful in integrated circuit fabrication. While most of the silicides are metallic in nature, some of them are semiconducting also. Among the semiconducting silicides, β phase of $FeSi_2$ is quite promising due to its direct band gap (0.83 to 0.89 eV) and is a potential candidate for the development of new optoelectronic devices compatible with the well known Si process technology. Usually this silicide is produced by evaporation of thin iron film on a Si substrate followed by thermal treatment at an appropriate temperature in inert atmosphere. But very less work has so far been reported on laser synthesis and modification of iron silicide. In the present work, we have prepared β-$FeSi_2$ using both CW CO_2 laser and Excimer ($XeCl_2$) pulsed laser, 5N purity Fe was deposited by electron beam evaporation using an Edward E306 A vacuum costing unit on both (100) and (111) p-Si wafers and annealed by CW CO_2 laser (energy density ranging from 250 to 400 J/S) and pulsed laser (05 to 90 J/S) respectively. Also some samples were prepared by only thermal annealing at suitable temperatures. XRD studies on laser annealed samples showed a flat diffraction pattern with broad peak of β-phase of iron silicide whereas the thermally annealed samples showed sharp peak around the same 2θ value. The semiamorphous nature of the laser annealed samples might be due to the damage produced by laser beam exposure with rapid cooling rate. However, after further thermal annealing the films showed a remarkable increase in the β-$FeSi_2$ peak intensity indicating a betterment of the quality of material. Both thermally grown and laser followed by thermally treated films were studied for optical absorption and reflectance. The reflectance spectra of these laser grown films showed distinct minima at around 1.4 μm and 1.35 μm. One of these transitions (~1.4μm) is due to band edge and the other one (~1.35μm) is at slightly higher energy. In contrast, the only thermally grown sample showed no such sharp minima. The detailed results from these characterisations will be presented.

Q6-7

Dielectric Properties and Electrical Conductivity Studies on Pure and Nd Doped Yttrium Aluminium Garnet (Yag)

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Garnets are useful as laser host materials and find extensive applications as device material in bubble memories. There is a meager work on electrical properties on garnets in general and in the present material in particular. Dielectric constant (ε) and loss (tan δ) on single crystals of pure and Nd doped yittrium aluminium garnet have been measured in the temperature range 30°-600°C and in the frequency range 1 - 100 kHz. AC conductivity was evaluated from the values of ε and tan δ. DC conductivity was also measured in the same temperature range.

The static dielectric constant ε for pure and doped crystals were ~11.5. The loss (tan δ) was in the order of 10^{-5}. There is a usual behaviour of dielectric constant and loss for pure YAG. Anomalies are observed for the doped crystal at certain temperatures. The dielectric behaviour and results on the conductivity measurements are discussed in the light of existing report on possible structural phase transition at high temperatures.

Q6-8

Phase Transition of Liquid Crystal using Thermo-acoustical Parameters

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In present investigation, an attempt has been made to evaluate various thermo-acoustical parameters of liquid crystal cholesterol propionate in terms of the coefficient of volume expansivity (α) at different temperatures. The thermo-acoustical parameters evaluated are Moelwyn-Hughe's parameter (C_1), reduced compressibility ($\bar{\beta}$), Sharma constant (S*), (S_0'), (S_0), isochoric temperature coefficient of volume expansivity (X'), isochoric temperature coefficient of internal pressure (X_1), dimensionless Gruneisen like parameter (F_0), the parameter (J_x), reduced volume ($\bar{V}$), characterstic volume (V*), free available volume (V_a), fractional free available volume (f), repulsive exponent of intermolecular potential (n*), Huggin's parameter (F), isobaric acoustical parameter (K), isothermal acoustical parameter (K'),isochoric acoustical parameter (K''), Anderson Gruneisen parameter (δ), molecular constant (n), dimensionless parameter (A*), dimensionless parameter (B*). When the mesophase transforms from a highly disordered isotropically liquid state to a more ordered cholesteric phase, α exhibit a high value which cause a sharp fall in S and enable to establish the transition temperature more precisely in liquid crystal. Other thermo-acoustical parameters also shows anomalous behaviour near the phase transition. This therefore provide a supporting evidence to the cholesteric isotropic transition of cholesteric propionate at 385 K.

Q7-9

Charge Conduction Mechanism in ITO-PPHT-CV-In P-N Junction Device

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Organic semiconducting polymeric or molecular materials, have drawn much attention in electronic & optoelectronic devices, because of their low cost, ease of processing and architectural flexibility at the molecular level itself. A number of Schottky barrier[1-2] as well as p-n junction[3-4] device, based on photoactive. Organic semiconducting polymeric & molecular materials have already been reported.

The present communication deals with the designing of a new p-n junction made with PPHT (poly (3-pheynl hydrazone thiophene) a p-type semiconducting polymer{5} and CV (crystal violet) an n-type organic dye{6}. The electrical and photoelectrical properties of the fabricated p-n junction, having configuration ITO-PPHT-CV-In, were studied by analysing its J-V characteristics, photoaction spectra and C-V characteristics, in dark. The J-V characteristics in dark shows rectification effect, which is due to the formation of a energy barrier between PPHT-CV organic layers. The charge transport mechanism in forward biased condition was investigated by plotting log J against V, which shows a straight line at low voltage region and space charge effect at high voltage region. The photoaction spectra reveals that the photogeneration of charge carriers take place at the interface between two organic layers due to the electron donor-acceptor interaction. The variation of $1/C^2$ with voltage (V) also shows the straight line at low frequencies indicating the formation of p-n junction between PPHT and CV layers.

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Q7-10

Bistable Switching and Electroclinic Effect of a Highly Twisted Ferroelectric Liquid Crystal Mixture

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Switching time (t_s), spontaneous polarization (P_s) and tortional bulk viscosity (γ_t in the SmC* phase of a low pitch planar oriented ferroelectric liquid crystal mixture FLC#- 474 of thickness

10 μm have been measured in the temperature range of 20 to 54°C by the polarization reversal method. Optical tilt angle (θ) in the SmC* phase and induced tilt angle (θ) in the SmA* phase produced by the electronic effect have been determined. The Curie temperature Tc*A* is found to be around 49°C. P_s comes out to be equal to 175 nC/cm^2 at 25°C. t_s, lies in the range of 7 ms to 1 ms and varies inversely with electric field E above a threshold field E_t. Both t_s and E_1 are found to decrease with temperature. The optical tilt angle θ in SmC* phase is determined to be around 30° at 20°C. The induced tilt angle θmd in the SmA* phase is around 15° near Tc*v* and is found to decrease with temperature.

Q7-11

Theoretical Study of Specific Heat of High-T_C Cuprates Super-Conductors

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We have considered the intra and interlayer pairing and excitonic type interlayer correlation in a model Hamiltonian after employing equation of motion method and Green's function technique. We have obtained expressions for the specific heat for inter and intra layer interactions.

Using the available experimental values of various parameters, we have made comparison for the system Y $Ba_2Cu_3O_7$ system. The agreement between theory and experiment is satisfactory. We have also made study of density of states critical field, free energy and iso-to-pe effect.

PQ1-1

Studies on Microhardness Property of Sm Substituted $Bi_2Sr_2Ca_{1-x}S_mCu_2O_{8+\delta}$ Superconducting Bulk Textured Crystals

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Bulk textured crystals of $Bi_2Sr_2Ca_{1-x}Sm_xCu_2O_{8+\delta}$ ($0.0 \leq x \leq 0.5$) were grown by floating zone technique with platinum strip as heater. The effect of Sm doping on the growth and superconducting properties of $Bi_2Sr_2Ca_{1-x}Sm_xCu_2O_{8+\delta}$ has been studied. Mechanical properties of these grown crystals have been studied with micro hardness measurement and the results are discussed in detail.

PQ1-2

vHs Scenario in High T_c $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ Superconductors : Pressure Effects

Bal K. Agrawal and Savitri Agrawal

The electronic structure and the hole concentrations in the recently discovered high T_c superconductor $HgBa_2CuO_{4+\delta}$ and $HgBa_2CaCu_2O_{6+\delta}$ (d = 0,1) have been investigated by employing a first principles full potential self consistent linear muffin tin orbital (LMTO) method with the local density functional theory in the local density approximation. The scalar relativistic effects have been considered.

The van Hove singularity (vHs) induced Cu-d and O-p peak which is seen to lie above the Fermi level in the $\delta = 0$ system. Thus, the occurrence of the superconducting behaviour observed in the $HgBa_2CuO_{4+\delta}$ with $\delta = 0.1$ appears to originate by hole filling of the $\delta = 0$ systems either by oxygenation or by other methods to achieve the pinning of the vHs peak at the Fermi level. The Fermi surface nesting area in the $\delta = 0$ compound is seen to be larger than that seen in the $\delta = 1$ compound. The calculation reveals that the vHs peak approaches towards the Fermi level predicting a possibility of enhancement of T_c at high pressure, a result which is in agreement with the experiments for $HgBa_2CuO_4$ the vHs is pinned at the Fermi level for a critical volume of $V/V_0 = 0.65$, V_0 being the normal volume. This volume may be achieved for a pressure of 24 GPa, a value in excellent agreement with the experimental results of Chu *et. al.*

For the two Cu-layer system $HgBa_2CaCu_2O_6$, the vHs peak is pinned at E_F for a relative crystal volume of $V/V_0 = 0.77$. One observes the Fermi surface nesting area to become maximum at this particular volume. On further reduction of the lattice volume, the vHs peak moves above and away from the E_F. This results correlate, with the observed behaviour of T_c with increased pressure and leads to the conclusion that T_c is maximum when vHs peak is pinned at E_F.

PQ1-3

Dynamical Conductivity of Semiconductor Superlattices

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Making use of Maxwell's equations, we calculated longitudinal and transverse macroscopic as well as microscopic dynamical conductivity of type-I superlattice. Our computed long wavelength macroscopic conductivity of a modulation doped superlattice significantly differ from Drude conductivity in low frequency regime (microwave and infra-red regime) for a superlattice. Macroscopic conductivity shows oscillatory behaviour along the direction of growth of superlattice. Oscillations in conductance along the direction of growth a superlattice has experimentally been observed. We studied propagation of transverse electromagnetic waves in a superlattice for all possible values of frequency and wave vector. Calculated

microscopic transverse conductivity exhibits poles along both real and imaginary values of frequency for real as well imaginary values of wave vector. Poles in screened polarizability function along imaginary axis has been called ghost plasmon in recent literature. It has been argued that ghost plasmons is a collective state and it is main cause of experimentally observed negative compressibility of 2D free electron gas. In analogy with ghost plasmons, we call the poles of microscopic transverse conductivity as ghost polaritons. We also find that there can be more than one penetration depths for a superlattice and one of them decreases with frequency. It is in contradiction of the behaviour of penetration depth of a free electron gas, which increases with frequency.

PQ1-4

Atomic Relaxation and Surface States of β- SiC (110) Surface

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The surface localized and resonance states of an unrelaxed and relaxed SiC (110) zinc-blende surfaces have been investigated within the local density approximation of density functional theory (DFT), employing a first-principles full-potential self- consistent linear-muffin-tin orbital (LMTO) method using a thicker (thirteen layers) slab. Intrinsic surface states appear in the fundamental energy gap for the unrelaxed surface. We have allowed non-bond-length-conserving relaxation of the surface atoms for obtaining minimum energy configuration. The shift in the surface states arising from the relaxation of atoms is small in comparison to other studied heteropolar covalent semiconductors because of the smaller value of the relaxation angle of SiC (110) surface. New surface states have been predicted in the valence band region. The present atomic geometry is somewhat different from that of other theoretical results. We observe an inward displacement of Si cation and an outward displacement of C anion both parallel and perpendicular to the surface, different from Sabisch *et. al.* No experimental data are available for comparison.

PQ1-5

First-Principles Calculation of Energy Gap in Quantum Dot

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We have investigated the electronic structure of various size quantum dots, by using a first principles self consistent full potential linear muffin tin orbital (FP-1 LMTO) method. The fundamental gap increases rapidly with decrease in size of the nano-crystal.

PO1-6

Calculation of Superconducting State Properties of Metallic Glass $Mg_{70}Zn_{30}$ Using Linear Potential

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The superconducting state properties viz. electron-phonon coupling strength (λ), Coulomb pseudopotential (μ^*), transition temperature (T_c), isotope effect exponent (α) and interaction strength (N_0V) are calculated for the metallic glass $Mg_{70}Zn_{30}$ using the screened pseudopotential proposed by Sharma and Kachhava (1979). The parameters so calculated are compared with available theoretical values and experimental data. The agreement is satisfactory. The present value of T_c is quite close to the value of T_c obtained using model potential proposed by Veljkovic and Slavic reported in an international conference ICDM-97 held at Jaipur.

PO1-7

Intercalation of Oxygen Species into Tl-Ba-Ca-Cu & Y-Ba- Cu Alloyed Layers by Room Temperature Electrochemical Technique

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Thin Film Superconductors Tl-Ba-Ca-CuO & Y-Ba-CuO were synthesised using the electrodeposition technique from a non-aqueous bath. Tl-Ba-Ca-Cu & Y-Ba-Cu alloy films were electrodeposited onto silver substrates at a deposition potentials of -1.25 V versus SCE & -1.75 V versus SCE respectively. Intercalation of oxygen species into Tl-Ba-Ca-Cu & Y-Ba-Cu alloy films were then carried out at room temperature using the electrodeposition technique. The room temperature electrochemical technique for oxygenation reduces the reaction time & avoids annealing at higher temperatures. Thereby, avoiding the release of Tl_2O_3 vapours into open laboratory while preparing Tl- Ba-Ca-CuO thin films. The Tl-Ba-Ca-CuO & Y-Ba-CuO thin films were prepared for different oxidation periods & studied for microstructural & electrical properties.

PO1-8

Electrosynthesis of Bi-Pb-Sr-Ca-CuO Superconducting Thin Films

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Superconducting films of Bi-Sr-Ca-CuO have been formed by sequential deposition of constituent metals onto silver substrate by using d.c. electrodeposition technique with dimethyl sulphoxide bath. First the BSCCO precursors are deposited at a constant potential of 0.67 V versus SCE onto silver. Then lead is electrodeposited onto BSCCO precursors at a constant

potential of -0.5 V versus SCE. The various preparative parameters such as deposition potential, current density, deposition time etc. are studied & optimised. These films are oxidised electrochemically at room temperature in alkaline (1NKOH) solutions. The electrochemical oxidation is carried out for 24 min. & 28 min. at room temperature. The samples shows the superconducting behaviour below 91 K and 98 K respectively.

SPO1-9

Pulse Electrodeposition of Hg-Ba-Ca-CuO Superconducting Thin Films from a Non-Aqueous Solution

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Quaternary alloyed films of the Hg-Ba-Ca-CuO with composition 1:2 : 1:2 have been prepared onto silver substrates from a dimethyl sulphoxide bath using the pulse electrodeposition technique. The Ba-Ca-Cu alloy films were first pulse plated onto silver substrate at a deposition potential of -1.2 V versus SCE at 25 Hz. These films were then annealed at 800°C for 8 hr. & mercury was deposited on alloyed Ba-Ca-CuO films at a potential of -1.3 V versus SCE using a square wave pulse of 25 Hz frequency. These films were then oxidised at 300°C for 6 hr. in oxygen atmosphere. The films thus obtained were Characterised by studying their microstructural & electrical properties.

SPO1-10

Coexistence of Superconductivity and Spin Glass Ordering

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The possible coexistence of superconductivity and spin glass ordering in $YBa_2(Cu_{1-x}Fe_x)_3O_{7+y}$ has been investigated by considering a microscopic Hamiltonian consisting of a pairing Hamiltonian involving oxygen holes and exchange Hamiltonian arising from 0.2p holes and localized magnetic spins from Fe 3d states using Greens function formalism. The randomness of the spins has been taken into account by considering a random occupation number nj. The superconducting transition temperature T_c is calculated and the depression of T_c with Edwards-Anderson spin glass order parameter $Q = <S^2>^2$ is studied. The expressions for spin glass temperature T_g,, supercondcting order parameter Δ have also been obtained. The phase diagram for coexistence region is also obtained. The results show that the coexistence of the two cooperative phenomena of superconductivity and spin glass ordering is a distinct possibility.

PQ1-11

Condensation Transition in Coupled Chaotic Dynamical Systems

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In a population of interacting Bose particles, a condensate is formed by a finite fraction of particles occupying the same quantum state. Mutual synchronization in a population of identical chaotic dynamical systems, is closely related to condensation phenomena in classical systems.

In a chaotic dynamical system, neighbouring states of the system diverge under dynamical evolution at an exponential rate. Thus a population of identical chaotic dynamical systems placed on a lattice in an ordered configuration (nearly the same state) will rapidly become disordered in the sense that the individual dynamical systems will be in states no longer close to each other. However, if the chaotic dynamical systems are coupled to each other. The systems tend to synchronize. The behaviour of the entire population depends on the conflicting tendencies—disorder due to chaoticity of individual dynamical systems and order due to coupling between the systems.

The nature of certain remarkable aspects. concerning the transition from a totally disordered state for low coupling to a totally ordered state for high coupling, reported in the case of a large population, is explored by studying small populations. Small populations do not seem to exhibit this remarkable behaviour, suggesting the emergence of a truly collective behaviour at some critical value of the population size.

PQ1-12

Phase-Coherence and amplitude-coherence

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Weight function $P\alpha$ in the diagonal representation of density operator $\rho = (\int d^2\alpha\, P(\alpha) |\, \alpha\!<\!>\!\alpha\,|$, is reduced to define separately the weight functions for phase, arg (α), and amplitude, $|\,\alpha\,|$, which leads to concepts of phase-coherence and amplitude-coherence. For a single-mode phase-coherent field, it is shown that we have hermitian operator of form, $\hat{a}\,\hat{\rho}\,e^{i\psi}$, where $\hat{a}$ is the annihilation operator and ψ is constant, and the normally ordered characteristic function, $\chi_N(\xi)$, is a function of only the imaginary part of $\xi\, e^{i\psi}$. For a single-mode amplitude-coherent field, it is shown that $\hat{a}\,\hat{\rho}\,\hat{a}^{+} = k\,\hat{\rho}$ *where* $\hat{a}^{+}$ is creation operator and k is a positive real constant. When the weight function for the field is quantum, each of the reduced weight function may or may not be quantum irrespective of the nature of the other.

PQ1-13

Valence Band Offset of Polar GaN/SiC (001) 2×2 Interfaces

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We present the results of a first principles scalar relativistic version of full potential self-consistent linear muffin tin orbital (LOMTO) with a density functional theory calculation for the electronic structure of the polar classic (001) superlattices. The calculation has been performed for two types of the interface containing mixed interface layer (i) Si (50%) and Ga(50%), (ii) C (50%) and N (50%). The relaxation of atoms have been considered. The calculated band offsets reveal strong sensitivity on the atomic positions in the interfacial region. For the relaxed surfaces, the calculated valence of valence band offsets are 1.12 eV for Si-Ga interface and 0.47 eV for the C-N interface.

PQ1-14

Role of vHs on T_c in Doped Fullerenes

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We investigate the role played by van Hove singularity (vHs) on the optimization of the value of T_c in doped fullerense $C_{60}K_3$ by employing a first-principles self-consistent full potential linear muffin tin orbital (FPLMTO) method in local density approximation (LDA). For C_{60}, the computed band structure shows an insulating behaviour with a direct band gap at the symmetry point X. The valence band originates from C_{60} molecule h_u states whereas the conduction band from the molecular t_{1u} states. Among the three types of C atoms the projected densities at the C(1) and C(2) atoms are higher than at C(3) atoms. The electronic charges in the muffin-tin C(1), C(2) and C(3) spheres are 1.990, 1.995 and 2.002 respectively.

In $C_{60}K_3$ the two types of K(1) and K(2) atoms occupy tetrahedral and interstitial positions, respectively. The band structure is very nearly similar to that of pure C_{60}. The three extra K electrons fill the t_{10} band upto half making $C_{60}K_3$ conducting. The K-induced states appear mostly in the conduction band region. We observe a saddle point leading to vHs in the vicinity of symmetry point L slightly shifted to-wards the F- point very near to the Fermi level. The saddle point lies at the Fermi level for a lattice constant of 14.51 A° (a 5% dilation) for which the highest value of T_c may be detected in the experiments.

PQ2-1

Absorption of Phonons by the (001) Inversion Layer of Si: Electron-Phonon Interaction in Two Dimensions

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We study the low temperature absorption of longitudinal acoustic phonons based on the model electron scattering in two-dimensional electron gas in the (001) inversion layer of Si through deformation potential interaction, the electron-phonon matrix element. By solving the phonon Boltzmann equation analytically and calculated numerically phonon absorption as a function of phonon wave vector and gate voltage, good agreement is obtained for both experimental and theoretical LA phonon absorption under the influence of dc field in a MOSFET structure, using the following material parameters: E_u = 9.0eV, E_d = -6.0eV, m = 0.19 m_o, $u_s = 9.4 \times 10^5$ cm/sec and P = 2.33 gm/cm^3.

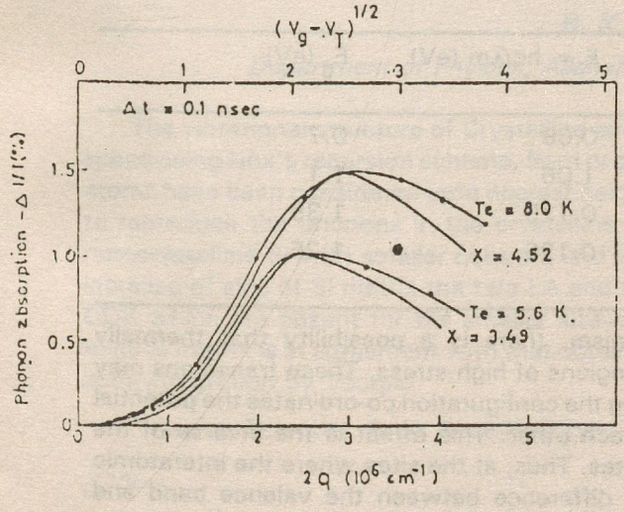


Fig. 1

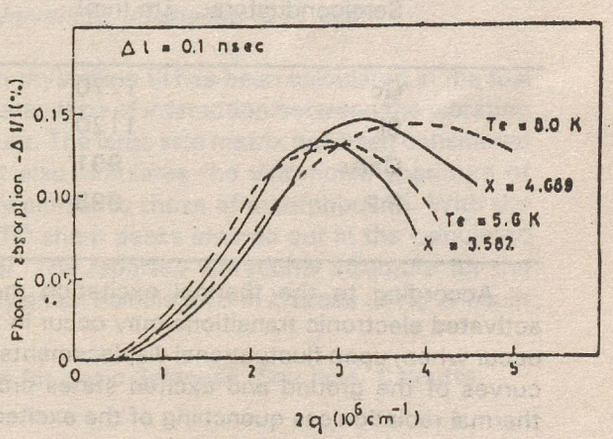


Fig. 2

It is interesting to note from Fig. 1, that the calculated absorption magnitude agrees with the experimental data of Hensel *et. al.*,[1] in the range of phonon wave vector q = (0 to 1.5) $\times 10^6$ cm^{-1} for T_e = 5.6, 8.0 K and X = u_d/u_s = 3.49, 4.52 respectively. Further, we estimate the phonon absorption in order to fit the theoretical results[1]. This is shown in Fig. 2, for the same electron temperature but different value of X. Our theory allow us to choose a free parameter to fit for both experimental and theory. Implication of this result will be discussed.

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PV-2-2

Deformation-Induced Thermal Excitation of Electrons in Semiconductors

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The emission of light takes place when the semiconductors like Si, Ge, GaAs, InP etc. are fractured or cleaved in vacuum or in ambients /1,2/. This phenomenon in semiconductors occurs due to the de-excitation of electrons that are raised to excited state when bond across the cleavage planes are ruptured due to the mechanical energy. The present paper reports that the light emission during fracture of semiconductors may occur due to the deformation-induced thermal excitation. Since these semiconductors are non-piezoelectric and charged dislocations do not exist, the light emission may not be due to the deformation- induced electrical processes.

The energy associated with the peak λm of the spectra of light emitted during fracture of semiconductors, generally approximates with the band gap energy E_g. (Table 1).

Table 1—λm and E_g for different semiconductors

Semiconductors	λm (nm)	$E = hc/\lambda m$ (eV)	E_g (eV)
Ge	1770	0.68	0.7
Si	1120	1.06	1.1
GaAs	991	0.125	1.35
InP	993	0.125	1.25

According to the thermal excitation mechanism, there is a possibility that thermally activated electronic transitions may occur in the regions of high stress. These transitions may occur when, upon fluctuational displacements along the configuration co-ordinates the potential curves of the ground and excited states cross each other. This effect is the inverse of the thermal radiationless quenching of the excited states. Thus, at the sites where the interatomic distance will be significantly higher, the energy difference between the valance band and conduction band may decrease. As a matter of the fact, electrons may jump thermally from the valance band to the conduction band and free electrons and holes will be produced. The subsequent radiative recombination of electrons and holes may give rise to the light emission.

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Key words = Semiconductors, Photon emission, Fracture.

PACS No. = 78.60, 68.25, 71.35.

PO2-3

First Principle Calculation of Electronic Properties of $Ga_{1-x}Al_xAs$ Alloys

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The first principle full potential self consistent linear muffin tin orbital method (FPLMTO) has been employed to investigate the electronic properties of III-V semiconducting $Ga_{1-x}Al_xAs$ alloys for x = 0.0, 0.125, 0.25, 0.375, 0.50, 0.625, 0.75, 0.875, & 1.0 in their ordered and random configurations. A linear variation of the lattice constant with the concentration of constituent atoms is seen in the alloys. The electronic structures have been computed for the whole concentration range of the alloys. A direct to indirect band gap crossover has been seen near the concentration x = 0.58 alongwith large band gap bowing below and above the crossover for both direct and indirect band gaps.

PO2-4

A Real Space Calculation of Vibrational Structure of Crystalline and Non-crystalline Si

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The vibrational structure of Crystalline and non-crystalline Si has been calculated in the real space using Nex's recursion scheme. Born or deLaunay type of interaction between the vibrating atoms have been considered upto nearest neighbours. The large size matrix has been considered to reproduce the phonons in the crystalline Si. It also simulates the vibrational spectrum of non-crystalline Si with smaller network and is very similar to those of amorphous Si. With the increase of size of Si matrix the two LA and two TO sharp peaks emerge out in the calculated DOS which are absent for the smaller size cluster. The reported vibrational structure for the large Si matrix is in agreement with that obtained by exact calculations in *k*-space using Brillouin zone integration by Thorpe.

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PO2-5

Recombination via Dangling Bonds in Amorphous Silicon

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Dangling bonds are the main recombination centers in amorphous silicon. Statistics of the recommendation via dangling bonds has been discussed in a recent paper[1] by Dhariwal *et. al.*, These expressions though complete are somewhat complicated due to three charge states and correlated energy levels. Halpern[2] has suggested that a two level model may work as a reasonably accurate simplification. We have analyzed and compared the recombination rate as obtained by two independent energy levels by using simple SRH theory and the complete

formula with correlated energy states. We find that for comparable capture cross-sections for neutral and charged states the two independent energy levels approximation does not give accurate result. However in practice capture cross-sections for charged states are larger than those for the neutral states. For a higher ratio of capture cross-sections the results of two level model agree with the exact result. This finding is important in amorphous semiconductor in which dangling bonds not only determine the recommendation rate but also the space charge density and in turn the built in electric field in p-i-n diodes and solar cells.

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PO26

Theory of Strain Field and Electric-Field Gradients in Dilute Alloys

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The Kanzaki lattice static method is generalized to investigate the strain field due to substitutional impurities in dilute alloys of fcc and bcc symmetries. The dielectric screening method is used to calculate host-host and host-impurity interatomic potentials for simple metal alloys and transition metal model potential is used for transition metal alloys. Considering the interactions upto second nearest neighbors (NNs), the impurity induced change in force constants and atomic displacements are calculated for Al, Cu and V alloys. These are found anisotropic and oscillatory in nature. The valence and size electric field gradients (EFGs) are generated simultaneously from the crystal potentials of the perfect and imperfect lattices. The EFGs are calculated at the displaced positions of different NNs of impurity without introducing any size strength parameter. The calculated results of atomic displacements and EFGs are found in good agreement with the experimental values.

PO27

Anharmonic Contribution to Static Displacements Due to Point Defects

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The static displacements due to point defects has been discussed in the framework of Green's function theory. The effect of anharmonic contributions has been explicitly incorporated which is expected to be important for strongly perturbing points defects. An interative procedure using static lattice Green's functions based on harmonic lattice model has been devised to evaluate the static displacements. A preliminary result regarding self-interstitials in copper is discussed.

PO2-8

Vibrational Density of States of Carbon Interstitials in Thorium

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Local vibrational density of states of carbon interstitials in thorium has been calculated using Green's function method. Carbon interstitials occupy octahedral site in the lattice of thorium. The calculated local spectrum is discussed in the light of neutron scattering measurements on the system.

PO2-9

Electrodeposition of CdS Thin Films for their Use in Photoelectrochemical Solar Cells

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The CdS films give best solar cell performance when deposited on titanium substrates from an aqueous solution containing 10cc of 1M $CdSO_4$, 25cc of 2M NH_3 solution and 10cc of 1M thiourea at 80°C. The optimum output was obtained when the thickness of the films was 8300A°. These films were photo-etched in a solution of 97% HCl and 3% HNO_3. CdS photoanode shows maximum stability in poly-sulphide solution containing 1M Na_2S, 1M and 1M NaOH. The chemical etching is found to improve short circuit current I_{sc} and fill factor whereas photoelectrochemical etching technique improves the stability of photoanode in polysulphide electrolyte. It is found that the crystalline size increases by annealing. The films annealed for longer periods show larger photocurrents. Annealed films have larger depletion layer width and minority carrier diffusion length. The larger depletion layer width increases the short circuit current, whereas, larger minority carrier diffusion length minimizes the rate of recombination losses. This increases the I_{SC} and V_{OC} and hence the conversion efficiency. The conversion efficiency and stability are found to improve by chemical etching of the semiconductor layer, because chemical etching pins Fermi level of CdS photoanode and promotes exchange current density.

PO2-10

Diluted Magnetic Semiconducting Alloys Based on III-V Compounds —Crystal Growth and Characterization

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Diluted magnetic semiconductors (DMS) have recently been paid attention for high speed electronic devices e.g. display panels, circulators and IR detectors. Partial substitution of the metal ions in the compound semiconductors by magnetic ions like Mn, Fe, Cr etc. within solid solubility limit develops some interesting properties due to interaction between the magnetic

ions and the carriers. This gives rise to enhanced mobility and other transport properties. Most of the work in this area so far reported are on II-VI compounds. We report here our investigations on III-V compounds based DMS e.g. $Ga_{1-x}Mn_xSb$ and $Ga_{1-x}Fe_xSb$. Mn and Fe were incorporated during crystal growth of GaSb by Bridgeman-Stockberger technique. Variation of Mn and Fe concentrations changed the band gap and mobility. For $Ga_{1-x}Mn_xSb$ magnetic studies reveal a paramagnetic to ferromagnetic transition with increasing Mn concentration. For Fe as diluent magnetic component in GaSb we studied the transport properties and optical properties. Variation of mobility with temperature in the temperature range 14K-100K showed a saturation in mobility at lower Fe concentration and exhibited a maxima at higher Fe concentration. An effort was made to explain the results in the light of different scattering phenomena. Optical measurements determined the p-type conductivity of the ternary alloys at all Mn and Fe concentrations. Also decrease in bandgap with increased Mn concentration indicated a trend of semiconducting to metal transition while for Fe no such transition was observed.

PQ2-11

Heavy Fermion Systems : Competition Between Kondo and RKKY Interactions

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Thermodynamic and transport properties for a Ce-based system, $CaCu_2Si_2$ are studied using the kondo and RKKY interaction Hamiltonian within the Abrikosov's pseudofermion representation in the presence of CEF at low temperatures (1K). Free energy and self energy expressions are obtained using the corresponding Feynmann diagrams. The pseudofermion representation is found to be more suited for strongly correlated systems with the advantage of built-in feature of the single occupancy state and removing the other spurious states. However, the present formulation has a limitation for the application in the range below 1K. It is found that the competition between Kondo contribution in $(J/N)^2$ and RKKY contribution in $I(J/N)^2$ decides the nature of overall behaviour in thermodynamic and transport properties. The Crystalline Electric Field splitting also manifests itself more significantly. This competition thus explains the anomalous characteristics exhibited by experimental data pertaining to heat capacity, electrical and thermal conductivity. Thermoelectric power and Hall effect are found to change signs in the appropriate temperature ranges. This approach may be further applied and extended to study other properties and interesting strongly correlated systems where the competition between these two interactions remains important.

PQ3-1

Soft Metal Schottky Diodes

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Schottky diodes are continuing to pose challenge towards understanding of the physical factors contributing to the evolution of potential barrier at the junction. The predominantly followed fabrication technique of forming such contacts by evaporation has been found to be

prone to many factors which affect the interface condition. Here in this paper we discuss on alternative route for fabrication and investigation of such diodes which may be more amenable to probe the physical conditions and their influence on the interface.

The fabrication and characterisation process of one of such diodes formed by mercury on Silicon will be described. It is found that the fabricated diodes have good stability with its little change % in its barrier height, ideality factor and series resistance over a period of hundred hours. The values of barrier heights are also found to be towards the Schottky limit in contrast to usual prediction that they should be nearer to Bardeen limit due to Fermi level pinning.

PQ3-2

Dielectric Behaviour of $PbNb_2O_6$ Single Crystals at Various Temperatures

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Dielectric studies are closely related to the heart of ferroelectricity and are used to determine fundamental ferroelectric mechanisms in a particular material. The results of present investigation shows that apart from thermally stable domains, unstable point domains do exist in $PbNb_2O_6$ single crystals, under the influence of low electric fields and under certain conditions. At equilibrium, a fixed number of domains exist in the given field but evaporate as soon as the electric field is removed. Further, it is observed that critical radius of nucleation (r_{cr}), wall energy (α) and critical energy of nucleation ($\Delta\omega_{cr}$) increases with temperature. It is also observed that the nucleation of unstable point domains are different in character from the thermally stable point domains that nucleate at the sites of the dislocations. The unstable point domains nucleate at the sites of the impurities in ferroelectric crystals. The low fields that required for the nucleation of domains exists in crystals even in the absence of the externally applied d.c. electric field, on account of the space charge.

PQ3-3

Thermal Dependence of D.C. Electrical Conductivity in Doped Polyaniline Conductiviting Polymers

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Conducting polymers are novel class of compounds in the field of scientific and industrial research, due to remarkable conductivity placed them in metallic group and termed as synthetic metals. Polypyrrole, polyaniline, polythiopene etc. are the most important class in conducting polymers. Polycrystalline conducting polyanilines were synthesised by peroxo-disulphate oxidation method in different acids at temperature 277K in nitrogen atmosphere.

The polymers were characterized by IR, U-V, visible, XRD and C,H,N elemental analysis techniques. D.C. electrical conductivity measurements were carried out by using four probe techniques of temperature range 298-393 K. The activation energy was found to be the order of 0.14 eV and confirms the semiconducting nature of studied polymers.

PO3-4

Phase Transitions in Alkali-ion Based Tungstate/Molybdate Ceramics

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In recent years, major work devoted towards the development of lead, rare earth and/or alkali ion based tungstates and molybdates have become the prospect of using them in various electronic devices. It has been observed that some molybdates and tungstates of general formula $ABCO_4$ (where A = monovalent large cation, B = small size cation, and C = Mo or W), belong to cristobalite structural family and they generally exhibit ferroelectric sequential phase transitions from high temperature cubic phase (point group $\bar{4}3m$) to low temperature ferroelectric disordered orthorhombic (point group *mm2*) and/or monoclinic (point group *m*) phase. In the present work preliminary structural and detailed dielectric study of some alkali ion based tungstates and molybdates: $NaLiWO_4$, $KLiWO_4$, $RbLiWO_4$, $NaLiMoO_4$, $KLiMoO_4$ and $RbLiMoO_4$ in ceramic form, will be presented. These compounds have been prepared by state reaction technique, XRD, SEM and resistivity study have also been carried. It is observed that they exhibit sequential phase transitions and have orthorhombic/monoclinic structure at room temperature. An attempt will be made to explain the various types of phase transitions present in them. A comparison among them will also be made.

PO3-5

Nematogenic Behaviour of 4'-Cyanobenzylidene-4- Methoxyaniline : A Theoretical Study

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The peculiar changes—characteristics of mesomorphic behaviour which occur at phase transitions, are primarily governed by the intermolecular interactions acting between sides, planes and ends of a pair of liquid crystalline molecules. In view of this, intermolecular interactions between a pair of 4'-cyanobenzylidene- 4-methoxyaniline (CBA) molecules have been evaluated using modified second order perturbation treatment along with multicentred—multipole expansion method. All valence electron method, CNDO/2, has been employed to compute the net atomic charge and corresponding dipole components located at each atomic centre of the liquid crystal molecule. On the basis of stacking and in-plane interaction energy studies, an attempt has been made to elucidate the nematogenic behaviour of the CBA molecule in terms of the translation freedom, orientational flexibility etc.

PO3-6

Experimental Studies on Physical Properties of a Lyotropic Liquid Crystal : N-Cetyl, N,N,N. Trimethylammonium Bromide

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Physical properties of N-cetyl N.N.N-trimethylammonium bromide (CTAB) in aqueous solution at various compositions have been studied using ultrasonic and allied physical methods. To see the effect of additives on the physical properties of the binary system, 0.05 N NaCl, 0.1 N NaCl and 0.5 N NaCl solutions have been used. Structural analysis based on physical parameters like ultrasonic velocity, density, dielectric constant, specific conductance and viscosity has been done. The change in the micellar form is indicated by the variation of the physical parameters within a range of concentration. These studies are helpful in understanding the liquid crystalline behaviour of CTAB in solution.

PO3-7

Application of Linear Potential for the Prediction of Bulk Modulus of Binary Metallic Glasses

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The linear potential proposed by Sharma and Kachhava has been used in deriving the expression for the bulk modulus for binary metallic glasses. The bulk modulus has been calculated. The bulk modulus is also computed using force constant K_e by Bhatia and Singh. The results so obtained are found in good agreement with other available theoretical values. The value of bulk modulus is used alongwith mean atomic mass density p and sound velocities of longitudinal $V_L(O)$ and $V_T(O)$ waves in low momentum region to estimate force constants of force constant model.

PO3-8

Investigation of Photoelectret Effect In $BaTiO_3$-ZnO Composites

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The present paper deals with photoelectric properties of $BaTiO_3$- ZnO composites. The samples were prepared by heat treatment technique. Different proportions of ZnO and $BaTiO_3$ were mixed thoroughly and fired at 800°C for 30 minutes in silica tubes under controlled

atmospheric condition. The measurements were made with parallel plate type capacitors, by sandwitching the material in polystyrene binder. The photoelectret cells are first polarized in presence of light and electric field, and later depolarized under illumination. The comparative dependence of photoelectret charge on various parameters such as applied field, intensity of illumination, time of polarization and effect of wavelength has been studied. The (5% $BaTiO_3$-95% ZnO) composites, stores more charges in comparison to (10% $BaTiO_3$-90% ZnO and (15% $BaTiO_3$-85% ZnO) composites.

PO3-9

Ultrasonic Attenuation in Vitreous Silica

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The two important acoustical parameters, viz., velocity of waves and absorption coefficient of acoustical energy propagating through a material are helpful in estimating the grain size, porosity, hardness of impact strength. A knowledge of attenuation in materials is essential in defining the limit of frequencies over which the material may be tested. In the present text these parameters with non-linearity constant have been evaluated along <111> crystallographic direction for longitudinal and shear waves between 77K-293K. The results are very interesting showing some kinks characterizing Vitreous Silica.

PO4-1

Infrared and Raman Spectra of Dl-Histidinium Dinitrate and L-Histidinium Sulphamate

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Molecular biology, in the last few decades, has had a very rapid growth and it has become necessary to understand molecular structure to get an insight into biological functioning. All living organisms contain proteins, which are large biological molecules. Amino acids, an important class of organic compounds, are therefore basic to life itself. The twenty amino acids that all living organisms use are grouped as essential and non- essential amino acids. Essential amino acids are those which must be supplied in the diet while the non-essential amino acids are those which can be formed within the body. Histidine is generally considered to be an essential amino acid.

Infrared and Raman spectral studies are capable of revealing structural features and changes due to biological functioning. In many cases they complement each other and Raman spectroscopy is a powerful tool to supplement any information obtained with the infrared spectra alone.

DL-histidinium dinitrate crystals were crystallized from an aqueous solution by slow evaporation using a 1.2 stoichiometric ratio of DL-histidine and nitric acid. The crystals were colourless and needle shaped. L-histidinium sulphamate was similarly crystallised with a 1:1 stoichiometric ratio of L- histidine and sulphamic acid.

A comparative study of the infrared and Raman spectra of DL- histidinium dinitrate and L-histidinium sulphamate helps determining the hydrogen bonding (inter and intra) in these crystals. The nitrate compound has the carboxyl group while the sulphamate compound has the ionised carboxyl group. However the protonated imidazolium ring makes the histidine group in both cases ionic hydrogen bonding. Several group frequencies have been shifted in both molecules indicating extensive.

Some of the forbidden modes of the nitrate group have been noticed. In addition, the degeneracy of certain modes of both the nitrate and sulphamate anions has been removed. This indicates that the symmetry of both these groups have been affected in their respective environments.

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PO4-2

Study of the K-Edges of 3d Transition Metal in Pure and Substituted Ferrites

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The metal K-edge absorption spectra of iron in 3d transition metal in pure and substituted ferrites are measured by X-ray absorption spectroscopy. Experiments are performed on metal foil or fine powders dusted on cellophane tape on Rigaku RU200 source. X-ray absorption near edge structure (NES) data evaluation, based on simple approach to determine bond lengths directly from features of the spectra have frequently been reported in literature. This approach is discussed critically taking unto account multiple scattering calculations as well as previously published data. All results together demonstrates that this approach can be used for simple molecules, but may be criticised for condensed matter analysis.

PQ4-2

Role of γ-ray Irradiation in Controlling Ferroelectric Behaviour of $PbNb_2O_6$ Single Crystals

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In the crystal, defects can be produced by high energy irradiation which changes the properties of the crystals after irradiation. The disappearance of ferroelectricity is associated with the removal of domain structure and an absence of hysteresis loop.

A new effect of irradiation in the form of disappearance of ferroelectricity in $PbNb_2O_6$ single crystals is reported. The irradiation alters the bonding between the dipole units responsible for switching. The main effect of γ-ray irradiation is to produce the oxygen vacancies in $PbNb_2O_6$ single crystals. It is observed that the number of oxygen vacancy sites also increases with increasing the dose of γ-irradiation, related to the disappearance of ferroelectricity in the crystals. Lead (Meta) Niobate crystals is found to obey the Curie-Weiss law upto a certain dose of γ-irradiation but above the critical value of oxygen vacancies the crystal falls to obey Curie-Weiss law. It may be due to removal of the forces responsible for ferroelectric behaviour of the structure after γ-irradiation, and hence it looses ferroelectricity. γ-irradiation may break the bonding between the different domains as well as the bonds within a domain that is responsible for ferroelectric nature of the material. Thus, it may be possible that a polydomain state of a specimen can be converted into a monodomain structure due to γ-ray irradiation.

PQ4-3

Photoacoustic Spectroscopy of Wheat Leaves Infected by Brown Rust Disease

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The Photoacoustic (PA) spectra of wheat leaves infected by brown rust were recorded at modulation frequencies 18 Hz and 228 Hz using 300w Xenon Arc lamp. The strength of PA signal were recorded, at different modulation frequencies using 632.8 nm radiation of the He-Ne laser to ascertain depth of penetration of the disease in the infected leaf tissue. For abaxial surface of the leave facing the incident radiation, the PA signal from leaves severely infected with brown rust disease is higher than that obtained from healthy leaves. This is in a marked contrast to a situation observed when adaxial surface is facing the incident radiation; the PA signal from severely infected leaves is lower than that from the intact leaf. In case of a horizontal spread of a disease in leaves, the tendency towards stem side was observed. Our results also reveal the progress of disease vertically through the leaf.

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PO4-4

Laser Raman Spectra and Molecular Polarizabilities of 2 Fluorobenzamide and 4-Fluorobenzamide

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Vibrational Spectroscopy is an important probe in elucidating the vibrational structure of molecules. The characteristic group frequencies play very important role in deciphering the vibrational frequencies. In the present paper, vibrational spectra of 2-fluorobenzamide and 4-fluorobenzamide have been studied in detail. Molecular polarizability/measurements have helped in locating the different vibrational modes of the molecules. Laser Raman spectra (alongwith molecular polarizabilities) have been recorded on Argon Ion Laser Raman Spectrometer in the region 50- 3800 cm^{-1}. The fundamental frequencies have been assigned and correlated with that of infrared frequencies recorded on Nicolet FTIR spectrometer in the region 400-4000 cm^{-1} and the vibrational model of the molecules has been proposed.

PO4-5

Study of Some Physical Properties of Polystyrene/Toulene Mixtures at Different Temperature and Concentrations

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Physical properties like viscosity, density and refractive index of polystyrene dissolved in toulene with different, concentrations (10 g/l-60 g/l) have been measured at different temperature (30- 80 °C) at the interval of 10 °C. Relative viscosity, specific viscosity, intrinsic viscosity and molar refractivity per unit molecular mass have been calculated from the observed experimental results. The experimental results show an increase of viscosity with concentration and decrease of viscosity with temperature within this experimented range. Refractive index also increases linearly with concentration and decreases with temperatures within this observed range as reported by previous workers.

PO4-6

Ultrasonic Studies of Polystyrene/Toulene mixture at Different Temperature and Concentration

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Measurement of ultrasonic velocity and density of polystyrene dissolved in toulene with different concentration (10 g/l-60 g/l) and at different temperature (20 °C-80 °C) have been done. From the measured velocity of sound and density, the adiabatic compressibility, acoustic

impedance and Rao number per average molecular weight have been calculated at different concentrations and temperature. The present study shows that the all above mentioned parameters are linear within the range of our concentration at each temperature.

PV4-7

Growth of CdTe Crystals by Direct Vapour Transport Technique

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Almost all standard techniques like Bridgemann Stockberger method, flux method, chemical vapour transport method, melt- growth have been successfully used to grow CdTe crystals. The only technique, so far not used repeatedly for growing CdTe crystals is the direct vapour transport technique. This is due to the large vapour pressure difference of Cd & Te. As this technique is known for growing crystals of high purity, we thought of exploiting the potential of this technique for the growth of CdTe crystals.

A stoichiometric mixture of CdTe was filled in a quartz ampoule of specific dimensions cleaned with standard cleaning solutions. The ampoule was sealed at a pressing of about 10^{-6} Torr. Sealed ampoule was kept in two zone furnace, which was specifically designed for the purpose and calibrated for its temperature profile. The temperature of source zone and growth zone were raised to 980°C at a rate of 10°C per hour. The growth zone temperature was oscillated between 980°C and 930°C thrice, to entire proper mixing of Cd and Te. Later on, the growth zone temperature was fixed at 930°C. The furnace was left with this temperature profile for 24 hrs. Then the temperature of both the zones were lowered down to room temperature at a rate of 5°C/hr. Crystals of CdTe were found to be grown in the ampoule. The grown crystals were characterised for their chemical composition and structure using EDAX & XRD techniques.

PV4-8

Preparation and Characterization of Ag_2S Thin Films Prepared by Successive Ionic Layer Adsorption and Reaction (Process)

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Semiconducting Ag_2S thin films were prepared on various substrates such as amorphous glass, semiconducting ITO-coated glass, single crystal wafers of GaP (111) and Si (111) from aqueous medium using successive ionic layer adsorption and reaction (SILAR) process. The films were deposited at optimized conditions and are as follows: The catonic precursor for Ag_2S was 0.05 M silver nitrate with pH ≈ 8. The source for sulphur ions was 0.4 M thiourea. The

adsorption and reaction time in the growth of Ag_2S were 15 seconds in each precursor with 30 seconds rinsing time in ion exchanged water between them. The number of deeps found to be 15 seconds. The process was carried out at room temperature (27 °C). At these optimized conditions, deposition is carried out onto various substrates.

The films deposited on FTO-coated glass substrates shows improved crystallinity than on amorphous glass which is further imported for GaP(111) and Si(111). The films deposited on glass substrates annealed at various (373 to 573 K) temperatures. The optical band gap energy changed from 1.12 to 0.9 eV and electrical resistivity changed from 3.162×10^4 to $1.995 \times 10^4 \Omega$-cm as a consequence of annealing.

From above, it is concluded that crystallinity of the film depends upon nature of the substrates where as optical bandgap energy and electrical resistivity decreases with annealing temperature.

PO4-9

Preparation and Characterization of Cu_xS Thin Films by Successive Ionic Layer Adsorption and Reaction (SILAR) Technique

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Semiconductor Cu_xS thin films of well controlled thickness and stoichiometry were prepared by a new, simple, inexpensive and less time consuming, Successive Ionic Layer Adsorption and Reaction (SILAR) technique. This method is based on immersion of substrate into separate cation and anion precursor solutions and before every immersion rinsing of substrate with deionized water to avoid homogenous precipitation. The Cu_xS thin films have been formed on microslide glass substrate with copper ions from 0.25 M copper sulphate solution and sulphur ions from 0.1 M thiourea solution. The pH of $CuSO_4$ solution is made 12 to 13 by adding excess ammonia. At number of deeps 20 and deep time 15 sec., and rinsing time 30 sec. the films are uniform and well adherent.

The annealing effect at 473 °K for 1 hr is also studied X-ray diffraction and optical absorption techniques are used for structural and optical characterizations. It was found that the films consist of following phases

CuS, $Cu_{1.765}S$, $Cu_{1.8}S$, $Cu_{1.96}S$, $Cu_{x(1.96>x>1.36)}S$, Cu_2S and $(Cu_{1.93}S)O_x$.

Band gap energies for direct and indirect transitions are found to be 2.38 and 1.4 eV for as deposited Cu_xS films and 2.56 eV and 1.9 eV for annealed Cu_xS films respectively. Thermoelectric power measurement reveals that Cu_xS is of p-type semiconductor

P094-10

Photoelectrochemical Cells Based on Nanocrystalline Chemically Deposited Bi_2S_3 Thin Films

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In recent years considerable interest has been shown in synthesis of thin semiconductor film by electrochemical and chemical deposition of colloidal semiconductors. Semiconductor nanocrystallites (quantum dots) whose radii are smaller than bulk excitation Bohr's radius constitute a class of materials intermediate between molecular and bulk forms of matter.

Bismuth thrisulphide (Bi_2S_3) nanocrystalline (40-100 nm) thin films have been deposited onto tin-oxide coated (FTO) glass substrates from an aqueous acidic bath (pH = 5). Bismuth nitrate and thioacetamide were used as Bi^{3+} and S^{2-} ion sources respectively. Films were deposited at lower temperature especially 10°C. To reduce grain size ethylenediaminetetra-acetic acid was used as complexing agent. Films of different thickness (500 to1700 A) have been deposited at different time periods.

Nanocrystalline films have number of applications such as designing systems for electrooptics and photoelectrochemical conversion of solar energy. An investigation has been made into the effect of photoelectrode thickness and grain size on the photovoltaic properties of bismuth trisulphide cells. The cell configuration is n-Bi_2S_3/0.25M NaOH + 0.25M Na_2S +0.25M S/C. The (photo) electrochemical characterizations of the films were carried out by studying current-voltage (I-V) characteristics in dark and light, photovoltaic output, capacitance voltage (C-V) and spectral response characteristics.

The thickness and grain size were found to cause significant changes in cell parameters. These studies reveal that the Bi_2S_3 thin films are n-type in conductivity. Short circuit current, open circuit voltage, percentage efficiency, fill factor are found to be increased where as flat band potential, series and shunt resistance are found to be decreased with increase in thickness and grain size of Bi_2S_3 films.

Reference

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PO4-11

Mossbauer Studies on Magnetic Anistropy of Fe-Metallic Glasses

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Magnetic anistropy of metallic glasses

$Fe_{80}B_{20}$, $Fe_{80}B_{10}Si_{10}$, $Fe_{60}Co_{20}B_{20}$, $Fe_{60}Co_{20}B_{10}Si_{10}$,

$Fe_{67}Co_{80}B_{14}Si_{1}$, $Fe_{50}Ni_{30}B_{10}Si_{10}$ and $Fe_{60}Ni_{20}B_{10}Si_{10}$ has been studied by using Mossbauer spectro-scopy. In the case of Fe^{57} Room temperature Mossbauer Spectra for all samples a small magnetic field of 1 Koe was applied parallel to the plane of the ribbon. From observed hyperfine sextets area ratios of 2, 5 lines ($A_{2,5}$) and 3, 4 lines ($A_{3,4}$) have been calculated. Further the ratio of $A_{2,5}$ to $A_{3,4}$ have been observed to be larger than 4/3. The variation in magnetization and magnetic anistropy are discussed on the basis of existing results.

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MATERIAL SCIENCE IN 21ST CENTURY

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When most of us were young children, we did not by any share of imagination think that science and technology would take ''man one day on the moon'', or that simulations of human beings: the robots, would work as substitutes for men as workers in factories/servants in household. Yet these and many other scientific wonders have seen the light of the day. Thus prognostication/peeping in the futures and predicting about materials of 21st century is a risky, exercise. Yet one foremost art of 'Science' is to foresee. The attempt to visualise possible materials and the science related to them in 21st century, may thus be justified.

Out of a variety of materials which may come through in 21st century those which would be at the zenith, according to present author would be (a) Smart/Intelligent materials (b) Microgravity (space) synthesised materials and (c) New Earth 21 Materials.

As regards the smart materials, we already have simple example e.g. photocromatic glasses are already in place. Those requiring more sophisticated components like material (skeleton), actuators (muscle) network of sensors (nervous system) and microprocessor based computational capabilities (brain), are being developed and may be at the centre stage in the 21st century. So me brief exposure to 'Smart Materials' would be presented. The space

(microgravity) grown materials have a very high price tag. However, the potentials that they hold e.g. fabrication of special ball bearings, preparation of semiconductors and pharmaceuticals without imperfections caused by gravity, are very attractive and at least for specific purposes space grown materials are bound to make their presence in the 21st century.

The Earth, because of pollution of urban environment, water and soil is becoming inhospitable place. Thus if Earth is going to continue to populate human beings, it has to be brought back to its greenery of the past one or two centuries. The role of materials for the mission project is paramount. The cleaner energy vector e.g. 'Hydrogen Energy' which would enable us to succeed in the 'New Earth 21' project is crucially dependent on the development of some exotic 21 Century materials; these will also be described and discussed.