MATSCIENCE

INSTITUTE OF MATHEMATICAL SCIENCES
MADRAS, INDIA

FIFTEENTH ANNIVERSARY

ANNUAL REPORT 1976

The Institute of Mathematical Sciences
Madras

"The pursuit of science is at its best
when it is a part of a way of life"

Annual Report 1976

Patron :

Mr. C. Subramaniam

Union Minister for Finance, Government of India.

Chairman of the Board of Governors :

Mr. R. V. Subrahmanian, I.A.S.

Adviser to the Governor, Government of Tamil Nadu.

Director :

Professor Alladi Ramakrishnan

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4.	Dr. P. K. Iyengar Director Physics Group Bhabha Atomic Research Centre Bombay.	**Member**
5.	Professor Alladi Ramakrishnan Director The Institute of Mathematical Sciences Madras.	**Member**
6.	Professor K. R. Unni The Institute of Mathematical Sciences Madras.	**Member**

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Professor Alladi Ramakrishnan Director The Institute of Mathematical Sciences Madras.	Member

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Madras. — **Chairman**

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Director
The Institute of Mathematical Sciences
Madras. — **Member**

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Delhi University
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Academic Council

Professor Alladi Ramakrishnan Director Institute of Mathematical Sciences Madras.	Chairman
Professor R. Vasudevan Institute of Mathematical Sciences Madras.	Member
Professor K. R. Unni Institute of Mathematical Sciences Madras.	Member
Professor N. R. Ranganathan Associate Professor Institute of Mathematical Sciences Madras.	Member
Professor T. S. Santhanam Associate Professor Institute of Mathematical Sciences Madras.	Member
Professor V. Radhakrishnan Assistant Professor Institute of Mathematical Sciences Madras.	Member
Professor K. H. Mariwalla Assistant Professor Institute of Mathematical Sciences Madras.	Member

General Information

Aims and Objects

1. To create and provide an atmosphere and environment suitable for creative work and the pursuit of knowledge and advanced learning in the mathematical sciences for their own sake.

2. To promote and conduct research and original investigation of fundamental sciences in general with particular emphasis on Mathematics, Applied Mathematics, Theoretical Physics and Astrophysics.

3. To foster a rigorous mathematical discipline, to stimulate a zest for creative work and cultivate a spirit of intellectual collaboration among academic workers in pure and applied branches of science.

4. To arrange lectures, meetings, seminars and symposia in pursuance of its academic work for the diffusion of scientific knowledge.

5. To invite scientists in India and abroad actively engaged in creative work to deliver lectures and participate in academic activity.

Academic Activities

The primary activity of the Institute is creative research in Mathematical Sciences. In pursuit of the objectives of the Institute, weekly seminars as well as series of lectures on various topics of interest, both by visiting scientists and academic staff of the Institute are held.

To commemorate the inauguration of the Institute an anniversary Symposium is held in January for which scientists from India and abroad are invited to deliver one hour addresses summarising their original work on recent advances in various branches of Mathematical Sciences.

Academic Staff

The Academic Staff consists of Senior Professors, Professors, Associate Professors. Assistant Professors, Visiting Professors, Visiting Scientists, and Research Fellows.

Ph.D. Programme

Facilities are available for postgraduate students to work for Ph.D. degree under the guidance of the academic staff of the Institute in various faculties, Senior and Junior research fellowships are awarded by the Institute.

The Standing Committee of the Inter-University Board of India and Ceylon at its meeting held in February 28, 1967 adopted a resolution recognising the Institute as a suitable centre for research work. In view of the above resolution the Institute is now recognised by the various Indian Universities as a centre for research or the doctorate degree in Theoretical Physics and Mathematics.

Publications

1. RESEARCH PAPERS (Preprints and reprints are available on request.)

2. MATSCIENCE REPORTS based on the lecture courses delivered at the Institute both by visiting scientists and academic staff (Price Rs. 10/- within India or U.S. $ 2-00 outside India). PROCEEDINGS OF THE SEMINARS AND CONFERENCES conducted by the Institute are also published as special Matscience Reports.

News of the Institute

Fourteenth Anniversary

The Fourteenth Anniversary of the Institute was celebrated on the 6th January 1976. Hon'ble Mr. V. R. Nedunchezhiyan, former Minister for Education, Government of Tamil Nadu, gave the anniversary address and the Director of the Institute presented the annual report.

The Fourteenth Anniversary Symposium was held for four days from 6th to 9th January 1976. Professor K. Bleuler, Professor W. Sandhas (West Germany), Professor M. Gourdin, Professor O. C.de Beauregard (France), Professor G. Pisent (Italy), Professor S. Panchapakesan and Professor T. E. S. Raghavan (U.S.A.) participated in the symposium besides the academic members of the Institute.

Conference on Matrix Algebra, Computational Methods and Number Theory

Matscience conducted a conference on Matrix Algebra, Computational Methods and Number Theory for four days from the 6th to the 9th september, 1976 in Mysore. Inaugurating the conference Professor Alladi Ramakrishnan, Director of the Institute, observed that such conferences conducted by Matscience every year afford a forum for presentation of original ideas by the younger generation of scientists. Work at Matscience relating to new connection between number theory and matrix analysis established by Dr. R. Jagannathan and Mr. Krishnaswami Alladi (University of California, Los Angeles) was presented. About thirty participants including post-graduate teachers and under-graduate students of promise took part in the conference. Besides the academic members of the Institute, a few scientists from different institutions in India lectured on various topics relating to the theme of the conference. The proceedings of the conference is being brought out as a Matscience Report.

Recent Developments of Physics

Professor Alladi Ramakrishnan inaugurated at Matscience a seminar series entitled Recent Developments of Physics on 14th February 1976 which was meant to disseminate information on recent developments in physics to the students and teachers of the various colleges in Madras City. The response to the seminar series by the academic community in Madras was very good. Various members of

academic staff reported on several topics in Physics in this series which was held every Saturday and Sunday till the middle of March 1976.

Professor K. R. Unni gave a course of lectures on Functional Analysis at the Institute.

Careers in Mathematical Sciences

Matscience was the venue of a seminar on 'Careers in Mathematical Sciences' organized by Mr. D. K. Oza, I.A.S., Director of Employment and Training, Government of Tamil Nadu, on 6th February 1976. Professor Alladi Ramakrishnan, Director of the Institute and scientists from the University of Madras spoke on the theme of the conference.

Academic Staff

Professor Alladi Ramakrishnan — **Director**
Professor R. Vasudevan
Professor K. R Unni
Professor N. R. Ranganathan
Professor T. S. Santhanam
Professor V. Radhakrishnan
Professor K. H. Mariwalla
Professor K. Srinivasa Rao

Senior Research Fellows:

Dr. Vimala Walter *
Dr. M. R. Subrahmanya *
Dr. R. Jagannathan *
Dr. V. V. Rama Rao
Dr. B. R. Gudagudi

Junior Research Fellows:

Mr. A. Vijayakumar *
Mrs. Kasturi Ramanathan *
Miss. S. Poornima
Miss. V. Indumathy
Miss. N. Indira **
Mr. V. M. Kothandaraman
Mr. V. N. Sridhar
Mr. J. S. Prakash
Mr. C. Jayaram
Mr. A. Bagavadhyram

Professor K. Sivasubramaniam ‡

Miss. S. Susila ***

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* Persons who have completed their tenure at the Institute.
** National Science Talent Scholar.
*** U. G. C. Teachers Trainee.
‡ Tamilnadu Research Scholar.

Administrative Staff

Accountant

Mr. A. J. Duraisingh*	(1962)
Mr. R. Venkatasubramanian	(1976)

Stenographers & Typist

Mr. R. Jayaraman	(1962)
Mr. N. S. Sampath	(1963)
Mr. S. Krishnan	(1963)
Mr. A. R. Balakrishnan	(1965)
Mr. R. Ganapathy	(1971)

Supporting Staff

Mr. D. Varadarajan	(1962)
Mr. M. Gangan	(1962)
Mr. S. Muthusigamani	(1964)
Mr. P. Govindan	(1968)
Mr. T. R. Narayanan	(1969)
Mr. G. Elumalai	(1969)
Mr. M. Kanniappan	(1962)
Mr. G. Venkatesan	(1972)
Mr. K. Chellakutti	(1973)
Mr. V. Jayaraman	(1975)
Mr. M. Munuswamy	(1975)
Mr. M. Selvaraj	(1976)

* Completed service on 30th September, 1976.

Delegations and Invitations

Professor Alladi Ramakrishnan, Director of the Institute, spent four weeks in U.S.A. and Canada on a seminar tour lecturing on his research work on 1. Theory of Stochastic Processes and their applications, 2. A new look at the Special Theory of Relativity and 3. L-Matrix Theory and its ramifications. He was invited to be the Chairman of a session in an international conference on Statistics and its applications held at Dayton, Ohio, U.S.A. from the 14th to the 21st June, 1976.

He also visited and lectured at the Fusion Energy Corporation, Princeton, U.S.A. on an invitation from its Director, Professor Bogdan Maglich.

During his stay in U.S.A. and Canada he delivered lectures at the Catholic University of America, Washington D.C.; University of California, Irvine; Colorado State University, Fort Collins; University of Dayton, Dayton; Fusion Energy Corporation, Princeton; State University of New York, Albany; University of Rochester, Rochester; University of Manitoba, Winnipeg and University of Calgary, Calgary, Canada.

Professor R. Vasudevan spent six months at the University of Southern California, Los Angeles, U.S.A. in response to an invitation from Professor R. E. Bellman, Department of Electrical Engineering, University of Southern California. During his stay, besides his research work, he co-authord a book on 'Wave equation—an imbedding approach' with Professor Bellman to be published by the American Elsevier Co. of New York. On his way back he lectured at various research centres including the Fusion Energy Corporation at Princeton and the Biophysics Department of State University of New York at Buffalo.

Professor K. R. Unni was invited by the Indian Institute of Technology, Madras, to give a course of lectures for the Second M.Sc. (Mathematics) students on Topology during August-October, 1976. He was invited to give a refresher course on Algebra from 20th to 31st December, 1976 under the College Science Improvement Programme at the women's Chiristain College, Madras.

Professor N. R. Ranganathan, participated in the International Symposium on Atomic, Molecular and Solid State Theory held at Sanibel Island, Florida,

U.S.A. from 18th to 24th January 1976 and presented his recent work on group theoretic approach to energy specturm of Bloch electrons in an external magnetic field. During his three-month stay abroad, he lectured in various universities: State University of Louisiana, Baton Rouge; University of Texas, Austin; University of California, Irvine; University of Syracuse, Syracuse, (U.S.A.); National University, Mexico; University of Waterloo, Waterloo; McMaster University, Hamilton; McGill University, Montreal and University of Montreal, Montreal, (Canada).

Professor K. H. Mariwalla participated in the International Symposium on Relativity and Unified Field Theory held at Calcutta from 27th December, 1975 to 1st January 1976, in which he presented an invited paper on perspectives and prospects of unified field theory and contributed another paper on 'Local conservation laws and symmetry breaking in General Relativity'. He also gave two lectures on 'Concept of Time and the problems of Relativistic Dynamics' and 'Observed dimensionality and matter creation concept of the general and projective relativity' at the Centre of Advanced Study in Applied Mathematics, Calcutta University in February 1976. He gave an invited talk on 'Observables and conservation laws in Relativity' at the International Dedication Seminar on Recent advances in Mathematics and its applications and Eighth Annual Conference of General Relativity and Gravitation (December 27, 1976—Jauuary 1, 1977) and conducted a mini school on 'Exterior calculus and Fibre bundle methods in Physics'.

Professor K. Srinivasa Rao gave a one hour invited lecture on photoproduction of pions in a seminar on Interactions of Elementary Particles on Nuclei held at Visva-Bharathi University, Santiniketan from the 15th to the 17th February 1976. He delivered a seminar at the Saha Institute of Nuclear Physics, Calcutta. He conducted a course on Computer Programming in the Department of Communication Engineering, Osmania University, Hyderabad from the 1st to the 10th March, 1976.

He spent two months from April 1976 in the Department of Physics Catholic University of America, Washington D.C. During his stay in U.S.A. he gave seminars in the Catholic University, Pennsylvania State University and presented a paper in the International Conference on Meson-Nuclear Physics held at Carnegie—Mellon University, Pittsburgh from 24th to the 28th May, 1976. He also participated in the Summer School and the Sixth International Colloquium of Group Theoretical Methods in Physics held at the University of Montreal from June 7 to July 9, 1976.

He presented his recent work on the symmetries of Racah coefficients in this conference in which he was also the Chairman of a session. He also lectured at McMaster University, Hamilton; M.I.T., Boston and Fusion Energy Corporation, Princeton.

He was deputed by the Director to visit the Hindustan Photo Films Ltd. Ootacamund and assist in discussions on the possibility of using computers in certain stages of film manufacturing processes. He participated in the annual Department of Atomic Energy symposium on Nuclear Physics and Solid State Physics held at the Gujarat University, Ahmedabad from the 27th to the 31st December, 1976. He delivered lectures on topics in Quantum Mechanics and Mathematical Physics in the Department of Physics, Vivekananda College.

Dr. Balachandra Gudagudi participated in the International Conference on Graph Theory held at the Indian Statistical Institute, Calcutta, from 20th to 25th December, 1976 and presented a paper entitled 'On the structure of Venn diagrams through Graph Theory'.

Invited Lectures

			1976
Professor M. Gourdin Department of Physics University of Paris VI Paris, France.	i. ii. iii.	'On Elementary Particle Physics' 'The ideal mixing for mesons in a six Quark Model' 'Vector and Tensor mesons: SU (6) symmetry'	January
Professor K. Bleuler Inst. for Theoretical Nuclear Physics University of Bonn Bonn, West Germany.	i. ii. iii.	'Geometrical methods in Hamilton-Jacobi Theory' 'Recent Developments in Nuclear Physics' 'On the structure of the Maxwellian Equation'	,,
Professor O. C. de Beauregard Institute of Henri Pioncare Paris, France.	i. ii.	'Einstein-Podolosky-Rosen Paradox' 'Evanascent Waves'	,,
Professor G. Pisent Galileo Galilei Inst. of Physics University of Padova Padova, Italy.	i. ii.	'A multichannel separable approach to Nucleon-Nuclear scattering' 'Finite Rank potentials in two body scattering problems'	,,
Professor W. Sandhas Institute for Physics University of Bonn Bonn, West Germany.	i. ii.	'Dynamical equations and approximation methods' 'Basic principles of multi-channel scattering theory' (two lectures)	,,
Professor S. Panchapakesan Department of Mathematics Southern Illinois University Carbondale, U.S.A.		'On selection and ranking problems in Statistics' (two lectures)	,,
Professor T. E. S. Raghavan University of Illinois Chicago, U.S.A.		'On recent results in game theory'	,,

Professor Shamsher Ali Director Department of Atomic Energy Centre Dacca, Bangladesh.	'Cluster models in nuclear physics'	January
Dr. M. Madhusudhana Rao Department of Physiology Vallabhai Patel Research Institute Delhi.	'Physiology of the brain'	February
Dr. George Marx Department of Atomic Physics Eotvos University, Budapest Hungary.	'Neutral currents in weak interactions' 'Big Bang : Ideas and facts'	,, March
Professor M. Dutta Satyendranath Bose Institute of Physical Sciences Calcutta.	'Objectivity criteria of classical Physics'	,,
Professor K. Varadarajan Mathematics Department University of Calgary Alberta, Canada.	'M. S. Fibrations of manifolds' (three lectures)	July
Professor M. R. C. McDowell Department of Applied Mathematics Royal Holloway College Surrey, England.	i. 'Dispersion Relations in Atomic Physics' ii. 'Review of Theoretical methods for electronic impact excitations of atomic system'	August
Dr. M. S. Seshadri Max Planck Institut fur Biophysik Frankfurt, West Germany.	'Passive electro-diffusive systems'	September
Professor Kurt Elfering Institute of Historical Sciences Munich, West Germany.	'Survey of the Mathematics of Aryabhatta'	October

Dr. A. K. Murthy Jadhavpur University Calcutta.		'Structure factor in classical liquids'	October
Professor C. J. Eliezer Department of Mathematics La Trobe University Melbourne, Australia.	i. ii.	'The Oscillator in applied mathematics' 'The invariant associated with oscillators'	December
Professor K. M. Khanna Head, Materials Science Department National Institute of Foundry & Forge Technology, Ranchi.		'Properties of interacting bosons'	,,
Professor K. Sivaprasad Department of Electrical Engineering University of New Hampshire Durham, U.S.A.		'Investigation of the layering of Ice'	,,

Research Papers

Professor Alladi Ramakrishnan

New Concepts in Matrix Theory, Journal of Mathematical Analysis and Applications (in Press).

Unnoticed Symmetries in Einstein Theory, Journal of Mathematical Analysis and Applications (in Press).

Professor R. Vasudevan

Completed the draft manuscript of a book entitled 'Wave equation—an imbedding approach' (with R. E. Bellman) to be published by the American Elsevier Co. of New York. This book of thirteen chapters presents novel methods of analysing linear wave propagation covering various techniques invented by the authors.

Compensation functions and method of images (with A. Vijayakumar & P. R. Vittal) (sent for publication in the Journal of Stochastic Theory).

Matrix Ricati Equations—iterative methods (with R. E. Bellman) (to be published in the Journal of Mathematical Analysis and Applications).

Professor N. R. Ranganathan

A New form of Magnetic Bloch Functions and Applications to Magnetic Band Structure Calculations, Phys. State. Solid (b) 74, *667* (1976) (with R. Jagannathan).

Professor K. H. Mariwalla

'Perspective and prospects of Unified Field Theory, Proc. Inter. Conf. on General Relativity and Unified Field Theories, Calcutta University, Mat. pp. 1 (1976) (in Press).

Local Conservation Laws and Symmetry Breaking in General Relativity, Proc. Int. Conf. on General Relativity and Unified Field Theories, Calcutta University Mat. pp. 2. (1976) (in Press).

Observables and Conservation Laws in Relativity, Int. Dedication Seminar on Recent Advances in Mathematics and its applications, Banaras, (to be published).

Professor K. Srinivasa Rao

Representation of the Racah coefficient as a generalized hypergeometric function (with K. Venkatesh), Proc. Int. Colloquium on Group Theoretical Methods in Phys., Montreal, 1976 (to appear).

On Coherent neutral pion photoproduction from the deuteron, (with S. Srinivasa Raghavan and K. Venkatesh), Few Body Dynamics, Proc. of VII Int. Conf. on Few-Body Problems in Nucl. and Particle Physics, North-Holland Pub. Co. (1976) p. 317.

A note on neutral pion photoproduction from the deuteron (with K. Venkatesh and S. Srinivasa Raghavan), Prog. Theor. Phys Vol. 55 (1976) p. 183.

Negative pion photoproduction and the ground state wave function of Carbon-12, Proc. Int. Topical Conf. on Meson-Nuclear Phys., Pittsburgh, (1976) Contributed papers, p. 188.

Dr. Balachandra Gudagudi

'On the structure of Venn diagrams through Graph Theory', Proceedings of Graph Theory Symposium at the Indian Statistical Institute, Calcutta (December 1976).

'Solution to a conjucture of D. C. Godwin and R. P. Sullivan, in Set Theory', (with V. M. Kothandaraman) (sent for publication to Mathematics Student).

Point Pathos Graphs of a Graph (Graphs defined on (O, 1) matrix) (Presented at the Graph Theory Symposium, held at the Indian Statistical Institute, Calcutta (December, 1976)

Dr. V. V. Rama Rao

On a problem of G. Birkhoff, (Communicated to Monatshaffe fur Mathematik).

SYMPOSIA, SEMINARS AND SUMMER SCHOOLS, CONDUCTED BY MATSCIENCE

Anniversary Symposia at MATSCIENCE, Madras

Year	*Title*	*Period*
1963	Resonance States in Elementary Particles	14–16, January
1964	Recent Trends in Theoretical Physics	3– 7, „
1965	Third Anniversary Symposium	3–12, „
1966	Fourth Anniversary Symposium	3– 9, „
1967	Fifth Anniversary Symposium	2–15, „
1968	Sixth Anniversary Symposium	17–31, „
1969	Seventh Anniversary Symposium	20–25, „
1970	Eighth Anniversary Symposium	10–14, „
1971	Ninth Anniversary Symposium	12–18, „
1972	Tenth Anniversary Symposium	8–10, „
1973	Eleventh Anniversary Symposium and International Conference on Functional Analysis	1– 7, „
1974	Twelfth Anniversary Symposium	10–12, „
1975	Thirteenth Anniversary Symposium	4, „
1976	Fourteenth Anniversary Symposium	6 –9, „

Summer Schools and Conferences

Year	*Title*	*Period*	*Venue*
1963	High Energy Physics	1—15, June	KODAIKANAL
1964	Theoretical Physics	24 Aug.—13 Sept.	BANGALORE
1965	Theoretical Physics	17 Aug.—4 Sept.	BANGALORE
1966	Recent Trends in Theoretical Physics	27 Sep.—15 Oct.	BANGALORE
1967–68	First Seminar in Analysis	20 Dec. 67—16 Jan. 68	MADRAS
1968	Fourth Matscience Summer School	24—28, Sept.	MADRAS
1968–69	Second Seminar in Analysis	26 Dec. 68—10 Jan. 69	MADRAS
1970	Frontiers of Physics	14—20, Sept.	OOTACAMUND
1970	Elementary Particles and Nuclear Physics	22—31, Jan.	BANGALORE
1970	Third Seminar in Analysis	18th Feb. to 2nd March	OOTACAMUND
1971	Clifford Algebra, its Generalization and Applications	30—31, January	OOTACAMUND
1971	Fourth Seminar in Analysis	1—10, February	OOTACAMUND
1971	Cosmology, Gravitation and Applications to Particle Theory	5—9, November	MYSORE
1971	Fourier Optics, Lasers and Holography	11—15, November	BANGALORE
1972	Twin Conferences 1. Fifth Seminar in analysis and 2. Symposium on Matrix Theory.	11—22, March	BANGALORE
1973	Nuclear Physics	1—5, March	BANGALORE

Year	*Title*	*Period*	*Venue*
1973	Numerical Analysis and Combinatorial Methods	9—16, March	BANGALORE
1973	Probability Theory and Stochastic Processes	24—30, Sept.	BANGALORE
1974	Sixth Seminar in Analysis	11—20, February	BANGALORE
1974	Mathematics in Medicine and Biology	12—23, February	BANGALORE
1974	Green's Functions	22—26, Sept.	MYSORE
1975	Seventh Seminar in Analysis	8—17, March	MYSORE
1975	Collective Phenomena in Nuclei and Solids	13—16, Dec.	MYSORE
1976	Computational Methods, Matrix Algebra and Number Theory	6—9, Sept.	MYSORE

SPECIAL ONE-DAY SYMPOSIA

1968	Mathematics as a stimulus to Physical thought (in honour of Professor Marhsall Stone)	29 Dec.	MADRAS
1969	Computers in Science and Industry	25 March	MADRAS
1970	IMPACT Conference on 'Coordinate Transformations and their Applications'	1 April	MADRAS
1970	IMPACT Conference on 'Devolopment in Aviation and their economic Impact of India'	20 Sept.	MADRAS
1971	Fifty Years of Mathematical Education in India	29 Dec.	MADRAS

MASTECH CONFERENCES

(Sponsored by the Council of Scientific and Industrial Research)

Year	*Title*	*Period*	*Venue*
1969	Matrix Analysis and Applications to Science and Technology	25 Sept. to 3 Oct.	BANGALORE
1970	Probability and Statistics and their Applications to Science and Technology	14—20, Jan.	MADRAS
1971	Statistical Mechanics and their Applications to Science and Technology	24—27, Jan.	BANGALORE
1971	Functional Analysis and its Applications to Science and Technology	14—17, Sept.	BANGALORE

INSERVICE TRAINING PROGRAMME

(Sponsored by the Directorate of Collegiate Education)

1973	Inservice Programme for the Mathematics Teachers	1—15, May	MADRAS

LIBRARY

Books and Periodicals :

During the year under report 610 new books including bound periodicals and 105 lecture notes were added to the library bringing the total number of volumes to 14,405. These include many of the recent publications in pure and applied mathematics and theoretical physics. We are regularly receiving periodicals and lecture notes from 50 institutions throughout the world in exchange to MATSCIENCE REPORTS and SEMINAR IN ANALYSIS.

Lists Published :

1. List of Preprints received in the library (issued Fortnightly).
2. List of New additions (issued Bi-monthly).
3. List of available MATSCIENCE REPORTS and SEMINAR IN ANALYSIS (issued yearly).
4. List of Institute Publications (Reprints & Preprints), (issued yearly).
5. List of Periodicals received in the library (issued yearly).

LIST OF AVAILABLE MATSCIENCE REPORTS AND SEMINAR IN ANALYSIS

Report No.	*Author(s)*	*Title*
9	L. I. Schiff	Lectures on Gravitation. 47 p. (1963).
55	H. S. Shapiro	Smoothing and approximation of functions. 109 p. (1966).
57	K. Srinivasa Rao & R. Sridhar	Nuclear models and nuclear matter. 202 p. (1967).
61	T. S. Santhanam	Group theory and unitary symmetry. 90 p. (1967).
62	R. H. Good	Description of particles with any spin and with internal symmetry. 51 p. (1968).

Report No.	*Author(s)*	*Title*
66	F. Riahi	Lectures on non-relativistic scattering theory. 62 p. (1969).
67	K. Srinivasa Rao (Ed.)	Proceedings of the one day symposium on computers in science and technology. 55 p. (1969).
69	P. K. Geetha	Topics in modern mathematics. 110 p. (1970).
71	A. R. Prasanna	General relativity and cosmology. 57 p. (1970).
72	A. R. Prasanna	Gravitational collapse and gravitational radiation. 69 p. (1971).
74	Krishnaswami Alladi	Contributions to number theory. 62 p. (1972).
75	Alladi Ramakrishnan	Essays on scientific topics. 73 p. (1972).
76	—	Proceedings of the conference on "Cosmology, Gravitation & Applications to Particle Theory", Bangalore, 1971. 289 p. (1973).
77	—	Proceedings of the conference on "Fourier Optics, Lasers & Holography", Bangalore 156 p. (1973).
78	—	Proceedings of the conference on "Nuclear Physics", Mysore, 1973. 284 p. (1973).
79	—	Proceedings of the conference on "Numerical Analysis & Combinatorial Methods", Bangalore, 1973.
80	Krishnaswami Alladi	Lectures on Diophantine Approximations. 55 p. (1974).
81	Alladi Ramakrishnan	Applications of the theory of stochastic processes to physical problems. 144 p. (1974).

Report No.	*Author(s)*	*Title*
82	Vimala Walter	On fundamental and interpolating Spline functions. 64 p. (1975).
83	Krishnaswami Alladi	New concepts in Arithmetic functions. 65 p. (1975).
84	K. H. Mariwalla	Introduction to Vectors, Tensors and Relativity. 153 p. (1975).
85	R. Vasudevan (Ed).	Proceedings of the conference on "Mathematics in Medicine and Biology", Bangalore, 1974. 221 p. (1975).

SEMINAR IN ANALYSIS

1	K. R. Unni	Lectures on Bernstein approximation problem. 107 p. (1969).
4	A. L. Brown	Abstract approximation theory. 118 p. (1970).
6	S. P. Singh	On Fixed point theorems. 157 p. (1975).

These Reports are available at Rs. 10/- (within India) & at $ 2.00 (outside India).

PROCEEDINGS OF THE CONFERENCE ON CLIFFORD ALGEBRA, ITS GENERALIZATION AND APPLICATIONS

—Conference organised by MATSCIENCE, 30th January–1st February 1971, held at Ootacamund, South India.

CONTENTS :

(103 p. (1972) Rs. 10/- within India and $ 2.00 outside India)

APPENDICES

LORENTZ TO GELL-MANN—CAN THE MASTERS BE RETOUCHED?

ALLADI RAMAKRISHNAN,
Matscience, Madras-600020.

Twentieth century physics emerged from two main streams of thought—relativity and quantum mechanics.

The special theory of relativity was formulated to resolve the paradox that the velocity of light is the same in all frames of reference. Lorentz, at the end of the nineteenth century, prepared the ground for the theory by discovering the transformation under which the electromagnetic equations of Maxwell are invariant. Einstein in 1905 realised that this was applicable to the mechanics of massive particles and was led to the velocity transformation formula and the equivalence of mass and energy. The two Masters created an almost perfect picture of the four dimensional world of space and time on the canvas of Newtonian mechanics.

Quantum mechanics was the outcome of the efforts to resolve the dual nature of light and matter, reconciling their particle and wave aspects. The basic structure of quantum mechanics was created between 1900 and 1928 by Planck, Bohr, Schrodinger, Pauli, Heisenberg and Max Born. With the induction of intrinsic spin and relativity, the stable edifice of relativistic quantum mechanics was completed through Dirac's formulation of the equation of electron in 1928. This theory had an unabated triumph till 1949 when Feynman devised an elegant graphical formalism which simplified calculations to such a degree that its origins were ignored or forgotten. With the work of Dirac and Feynman, physics attained such a state of completeness that Q.E.D. or quantum electrodynamics was considered Q.E.D., established beyond doubt. However as it often happens in the history of science the completion of one problem is just the beginning of another. With the proliferation of fundamental particles it was found inadequate to describe elementary particles by dynamical quantum numbers only. The particles had to be labelled also by internal quantum numbers, the meaning of which is unclear even to-day. However

the mathematics of labelling, first devised by Heisenberg through the introduction of isotopic spin reached a state of logical completion under the direction of Gell-Mann who initiated the Gell-Mann era of modern physics in 1954 with the famous Gell-Mann-Nishijima relation between the internal quantum numbers charge, isotopic spin and strangeness. However, during the last few years experiments have confronted the theoretician with unsolved questions relating to three main problems—unifying various types of interactions, bridging the gap between perturbation theory and strong interactions and imbedding new quantum numbers like charm into a meaningful structure with group theoretical properties. The question therefore arises whether there is need to reexamine the Masters or atleast retouch their work bringing into bold relief the outstanding problems against the background of those that have been solved satisfactorily.

Relativity theory of Lorentz and Einstein primarily deals with the transformation formula connecting spatial and temporal separations of two events in one frame with the corresponding separations in another frame moving with uniform velocity with respect to the first. A close examination of the literature for the past seventy years since the birth of special relativity reveals that the concept of an *event* has not been precisely defined and that is why intrepid attempts were made to postulate faster than light particles just by making the mass imaginary in the expressions for energy and momentum. The precise identification of an event with the observation of a *point massive parlicle* has led us to the conclusion that *space-like* separations relate to events connected with *two* different particles while *time-like* separations connect events relating to a *single* particle, thus rendering the concept of a tachyon meaningless. We were also able to cast the volocity transformation formula in a symmetrical form by taking velocities of particles relative to one another in a *cyclic* sequence. It was possible to define also a function of velocity called *Bias* with an elegant multiplicative property. It has the equally elegant interpretation that its square root is the factor by which the spatial and temporal separation of events relating to a massless particle are altered in different frames of reference preserving the invariance of the velocity of the massless particle. The developments reveal unnoticed symmetries in the Einstein-Lorentz theory and dispel the ghost of the tachyon from the minds of the physicists.

The confluence of relativity and quantum mechanics was achieved when Dirac just wrote down his famous equation in 1928. This achievement was made possible

since he was able to construct four mutually anticommuting matrices so that the Hamiltonian was consistent with the quadratic relativistic relation between energy, momentum and mass. Earlier, in non-relativistic quantum mechanics three mutually anti-commuting matrices were found sufficient to include the concept of intrinsic spin. It was immediately noticed by Dirac that the quantum mechanical concept of spin was also imbedded in his Hamiltonian. In the years of uninterrupted triumph that followed the birth of relativistic quantum mechanics, the study of the mathematical significance of the transition from Pauli to Dirac matrices was considered quite academic and therefore ignored. But it was obvious that it was still a live and unsolved problem since immediately after Dirac's formulation, Pauli attempted such a study and as late as 1956, Feynman himself raised the question of the relationship between spin and relativity in his famous Caltech lectures even after the total triumph of his graphical formalism in electrodynamics.

It was necessary to strive for an understanding of the mathematical procedure of obtaining Dirac matrices from the basic Pauli set. It seemed the right time to do so since the spirit of the hour demanded a re-examination of the whole structure from the point of view of mathematical rigour and logical precision. To our surprise we found that the procedure which Dirac used was of such profound and general significance that it could be extended into a grammar of anticommuting matrices, the ramifications of which give us a better insight into various branches of theoretical physics—relativity, complementarity, propagator formalism and the fundamental concepts of spin and mass of elementary particles. Even more surprising was the possibility of enlarging the concept of anticommutation to ω-commutation where ω is a general root of unity. This led to a hitherto unknown generalization of the Gell-Mann-Nishijima relation in which additional quantum numbers could be included in a logical self-consistent manner. During the last decade thousands of scientists in universities and laboratories have been ceaselessly trying to comprehend the significance of new quantum numbers that had to be introduced into the Gell-Mann-Nishijima relation. It is our hope that the generalised Clifford algebra with its close connection with the Gell-Mann unitary symmetry will be a useful mathematical probe into the domain of internal quantum numbers.

Since 1949 the Feynman graphical formalism has dominated the mind and heart of the theoretical physicist, particularly because of its extraordinary emphasis on the manifest relativistic covariance at every stage of the description of the quantum mechanical processes. However the concept of *virtual states* defined by

the Feynman propagator made it difficult to interpret symmetry transformations like charge conjugation, parity and time reversal for such states though these could be applied meaningfully for the overall process. The main merit of the Feynman formalism was that a single Feynman diagram with n vertices corresponds to n! terms in the old fashioned relativistic field theory. But the equality of the perturbation expansions in Feynman formalism to that in covariant field theory was achieved only after painstaking efforts through laborious longwinded arguments. It was shown if only we decompose the Feynman propagators into positive and negative energy 'arms', a single Feynman diagram splits into 2^{n-1} diagrams which we call patterns and the correspondence between the 2^{n-1} patterns and n! terms of field theory can be made 'manifest' in a manner as to enhance the 'topological beauty' of a Feynman diagram which consists essentially in choosing the *vertices in a preferred sequence*. The fact that the terms corresponding to patterns are not covariant should not worry us any more than the noncovariance of n! terms since the covariance is preserved for the sums in both the cases.

This idea of the decomposition of the propagator was suggested and used by us in a series of papers wherein it was shown that considerable insight can be gained if we recognize that the four-dimensional transforms of singular functions occurring in perturbation theory can be obtained in two stages, a three-dimensional transformation over space and one dimensional tranform over time. This quite naturally leads to the decomposition of the propagator. The use of a simple lemma in complex variable theory combined with the conservation law of energy strikingly bring to light new facets of the topological structure of Feynman diagrams. The energy conservation is expressed as the vanishing of the sum of energy imbalances associated with vertices rather than with propagators, an idea introduced by the author in 1963. The various terms and their signs fit perfectly like 'pennies in a slot' so that the connection between old fashioned perturbation theory and Feynman formalism can be studied 'outside-in' and 'inside out'.

Physics today is faced with challenges, paradoxical, puzzling, strange and charming, as startling experimental results emerge from the great accelerator laboratories of the world. New particles demand new Masters, as bold and innovative as their predecessors. Somewhere in this teeming world there is being born an Einstein or a Lorentz destined to usher in the physics of the twentyfirst century.

21 December 1976.

LIST OF PERSONS WHO OBTAINED Ph.D. DEGREE UNDER THE GUIDANCE OF PROFESSOR ALLADI RAMAKRISHNAN

Name	*Year*	*Present position*	*Country*
Dr. P. M. Mathews	1956	Professor	India
Dr. S. K. Srinivasan	1957	Professor	India
Dr. V. Radhakrishnan	1958	A. Professor	MATSCIENCE
*Dr. V. K. Viswanathan	1958	Senior Scientist	U.S.A.
°Dr. P. Rajagopal	1959	A. Professor	Germany
Dr. R. Vasudevan	1960	Professor	MATSCIENCE
Dr. N. R. Ranganathan	1961	A. Professor	MATSCIENCE
*Dr. T. K. Radha	1962	Post doctoral	Canada
*Dr. Thunga Satyapal	1962	A. Professor	U.S.A.
*Dr. A. P. Balachandran	1962	Professor	U.S.A.
*Dr. N. G. Deshpande	1962	A. Professor	U.S.A.
Dr. V. Devanathan	1963	Professor	India
Dr. K. Venkatesan	1963	A. Professor	India
Dr. G. Bhamathi	1963	Professor	India
Dr. S. Indumathi	1963	Post doctoral	India
Dr. G. Ramachandran	1963	Reader	India
*Dr. K. Raman	1964	A. Professor	U.S.A.
*Dr. R. K. Umerjee	1964	Scientist	U.S.A.
*Dr. K. Ananthanarayanan	1965	A. Professor	Canada
*Dr. G. Jagannathan	1965	Post doctoral	U.S.A.
*Dr. P. Sridhar Rao	1965	Post doctoral	U.S.A.
Dr. T. S. Shankara	1969	A. Professor	India
Dr. T. S. Santhanam	1970	A. Professor	MATSCIENCE
Dr. K. Srinivasa Rao	1970	A. Professor	MATSCIENCE
*Dr. P. S. Chandrasekaran	1971	Post doctoral	U.S.A.
Dr. R. Sridhar	1971	A. Professor	India
Dr. A. Sundaram	1971	A. Professor	India
*Dr. Nalini B. Menon	1972	Post doctoral	U.S.A.
Dr. A. R. Tekumalla	1975	A. Professor	India
Dr. R. Jagannathan	1976	Lecturer	India

*** Those who have settled abroad.**

LIST OF INSTITUTIONS AT WHICH PROFESSOR ALLADI RAMAKRISHNAN, DIRECTOR, MATSCIENCE, GAVE LECTURES ON HIS RESEARCH WORK

UNITED STATES OF AMERICA

University of Arizona at Tempe (1970)
Bell Telephone Laboratories, New Jersey (1963)
Boeing Research Laboratories, Seattle, Washington (1968–69)
Boston University, Boston, (1967)
Catholic University of America, Washington D.C. (1976)
University of California, Berkeley (1962, 65, 71)
University of California, Irvine (1966, 71–74, 76)
University of California, Los Angeles (1962, 69)
University of California at Riverside (1971, 72–74)
University of Southern California (1968, 72, 76)
Case Institute of Technology, Cleveland (1958)
University of Chicago, Chicago (1956)
University of Colorado, Boulder (1967)
Colorado State University, Fort Collins (1976)
Cornell University, Ithaca (1967)
Courant Institute of Mathematical Sciences, New York (1967, 73)
University of Dayton, Dayton, Ohio (1968, 70, 76)
Dougals Aircraft Corporation, New York (1966–69)
University of Southern Illinois, Carbondale (1973)
General Motors Research Laboratories, Detroit, Michigan (1969)
University of Hawaii, Honolulu (1966–69)
Hughes Research Laboratories, Malibu, California (1962)
Howard University, Washington, D. C. (1971)
Illinois Institute of Technology, Chicago (1958)
University of Illinois, Urbana (1970)
Florida State University, Tallahassee, Florida (1974)
Fusion Energy Corporation, Princeton, (1976)
Institute for Advanced Study, Princeton (1957–58)
Massachusetts Institute of Technology, Cambridge, Mass (1956)
Institute of Theoretical Physics, Cambridge (1968)
Iowa State University, Iowa (1971)
Kent State University, Kent, Ohio (1975)
Lockheed Aircraft Corporation, New York (1969)
St. Louis University, St. Louis (1966–71)
University of Maryland, Maryland (1958)
Oklahoma State University, Stillwater, Oklahoma (1975)
Ohio State University, Columbus, Ohio (1974)
U. S. Naval Research Laboratory, Washington, D. C. (1958–74)
New York State University, Buffalo (1967–70, 72)

New York State University, Albany (1976)
University of New Hampshire, Dover (1975)
University of North Carolina, Chapel Hill (1971)
North Texas University, Denton (1969–70)
Oak Ridge National Laboratory, Tennessee (1970, 74)
National Bureau of Standards, Washington (1962, 74)
Pennsylvania State University, Pennsylvania (1972, 73)
Purdue University, Lafayette (1968, 70)
Rand Corporation, California (1962–71)
University of Rhode Island, Kingston (1971, 72)
Rutgers University, New Jersey (1971–72)
University of Rochester, Rochester (1963–67, 76)
University of Southern California, Los Angeles (1967–72)
Stanford University, Stanford (1962–72)
State College, Long Beach, California (1966–70)
SanJose State University, SanJose, Calif (1974, 75)
Syracuse University, Syracuse (1966, 69, 72)
University of Texas, Arlington, Taxas (1975)
University of Texas at Austin (1970)
University of Texas at Dallas (1970–71, 73–75)
Thomas J. Watson Research Center, IBM, New York (1971)
Utah State University, Logan, Utah (1971–72)
University of Washington, Seattle (1967–69)
University of Wisconsin at Madison (1966–70)
University of Wisconsin at Milwaukee (1966, 67, 71)
Wright–Patterson Air Force Centre, Dayton, Ohio (1968, 70, 76)
University of Wyoming, Laramie (1972)
Yeshiva University, New York (1967–72, 75)

ENGLAND

University of Edinburgh, Edinburgh (1949)
Imperial College of Science and Technology, London (1960, 63, 67, 69)
University of Manchester, Manchester (1949, 56)
Oxford University, Oxford (1950, 60)
Physical Society of Great Britain, Birmingham (1949)
University of York, York (1974, 75)

AUSTRALIA

Australian National University, Canberra (1954, 71, 73)
Latrobe University, Melbourne (1954, 71)
University of Melbourne (1954, 71, 73)
University of Sydney, Sydney (1954, 71, 73)

Monash University, Melbourne (1973)
University of Adelaide, Adelaide (1973)
University of Western Australia (1973)

CANADA

University of Alberta, Edmonton (1969)
Carleton University, Ottawa (1969)
University of Ottawa, Ottawa (1958)
Sir George Williams University, Montreal (1971, 72)
McGill University, Montreal (1971–72)
University of Montreal, Montreal (1968, 71, 72, 75)
National Research Council, Ottawa (1958)
Simon Fraser University, Vancouver (1958)
University of Toronto, Toronto (1968)
University of Manitoba, Winnipeg (1973, 74, 76)
University of Calgary, Alberta (1976)

WEST GERMANY

University of Bonn, Bonn (1971)
University of Gottingen, Gottingen (1956)
University of Heidelberg, Heidelberg (1956)
University of Marburg, Marburg (1956, 60)
University of Stuttgart, Stuttgart (1956)
University of Wurzburg (1975)

U. S. S. R.

Institute of Nuclear Research, DUBNA (1964)
Academy of Sciences, Moscow (1968)
Physical-Technical Institute, Academy of Sciences, Leningrad (1968)

JAPAN

University of Kyoto, Kyoto (1956)
Osaka University, Osaka (1956)
Tokyo University of Education, Tokyo (1966, 70)
Yukawa Hall, Kyoto (1956)

BELGIUM

Department of Mathematics, University of Liege, Liege (1971, 75)
Department of Physics, University of Liege, Liege (1971)

IRELAND

University of Dublin, Dublin (1949–74)
Dublin Institute for Advanced Studies, Dublin (1950)

SWEDEN

Cramer's Institute, Stockholm (1950)
University of Uppsala, Uppsala (1950)

NORWAY

University of Oslo, Oslo (1960)

SWITZERLAND

University of Berne, Berne (1960, 69)
CERN, Geneva (1960, 62, 66)
E.T.H. Zurich (Federal Institute of Technology), Zurich (1950)
University of Geneva, Geneva (1967)
Swiss Physical Society, Winterthur (1960)
University of Zurich, Zurich (1950, 56)

NEW ZEALAND

University of Canterbury, Christchurch (1971)

FRANCE

University of Paris, Orsay (1966)
Institute of Henri Poincare, Paris (1960, 66)
C. E. N., Saclay (1964, 65, 67–69)

ITALY

International Centre for Theoretical Physics, Trieste (1963, 65, 67, 68, 70, 74, 75)
University of Naples, Naples (1967)
University of Padua, Padua (1966–69)
University of Rome, Rome (1966, 69)

SINGAPORE

University of Singapore, Singapore (1967)

IRAN

Aria-Mehr University, Teheran (1968)

DENMARK

Bohr Institute, Copenhagan (1950, 1960)

HONGKONG

University of Hong Kong (1975)