SECOND ANNUAL MEET OF
Prof. S. MINAKSHI SUNDARAM MEMORIAL SOCIETY

and

One Day Seminar on
CURRENT TRENDS IN MATHEMATICAL MODELLING

SOUVENIR

22nd October, 2011

PVP Siddhartha Institute of Technology
Vijayawada - 520 007

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From the Desk of Organizing Secretary

From times immemorial, Mathematics has been playing a crucial role in the development of Science and technology and the contribution of Indian Mathematicians from ancient times to modern is quite significant. Prof. S. Minakshisundaram was an outstanding Mathematician of 20^{th} century who adorned the Departments of Mathematical Physics (now Applied Mathematics) and Mathematics, at Andhra University, Visakhapatnam from 1940 to late 1960's and influenced a large number of fertile minds through his thought provoking and motivating lectures. His Research work of 1940's was so great that it influenced the refinement of the famous Atiyah -- Singer – Index Theorem, one of the greatest theorems of 20^{th} century.

Some admirers and proud students of late Prof. Meenakshisundaram joined together recently and with a view to perpetuate the memory of their teacher and researcher par excellence, for the posterity, have formed the society by name Prof. S Meenakshisundaram Memorial Society. The inaugural meet of the society was held at the Department of Mathematics , National Institute of Technology, Warangal on 22^{nd} October, 2010.

We are privileged to host the Second annual meet of the Society at our Institute and we are extremely grateful to the Prof. SMS Memorial Society for accepting to have their second annual meet here followed by a one day seminar on Current Trends in Mathematical Modelling. I am grateful to the Members of Siddhartha Academy of General & Technical Education and in particular to our Principal, Prof. P. Venkateswarlu, PVPSIT for extending all the necessary encouragement and facilities to organize the present program. I express my heartfelt thanks to Prof. T.K.V. Iyengar, Professor of Mathematics, NIT, Warangal , an illustrious student of Prof.SMS and the Founder Secretary of Prof. SMS Memorial Society, who helped me with his thoughtful advises from time to time in organizing the meet and seminar.

The deliberations at the meet and the seminar, I am sure, will influence not only the delegates attending the but also the budding Research Scholars around in shaping their careers. I wish the Delegates a fruitful interaction in the program.

B.D.C.N Prasad

Organizing Secretary

About P V P Siddhartha Institute of Technology, Vijayawada

After Independence, when higher education was very much needed and education facilities for technical students were very limited, some philanthropists with their vision begot educational institutions under the aegis of Siddhartha Academy of General & Technical Education. Understanding the desirability of skilled technocrats, the Academy started its second engineering college, Prasad V Potluri Siddhartha Institute of Technology in 1998. Away from the hurly-burly life of the citizens, from the commotion of the city, in a serene atmosphere in the midst of grandiose green lush, the college was established. During the last 13 years of blooming existence, the institute has been pacing with excellent track – records and craving to create a niche for itself fabricating extraordinary professionals with exceptional innovative and analytical skills.

The Institute has been offering instruction in eight branches viz CE, ME, ECE, CSE, EEE, IT, ECM & AE at undergraduate level with an annual intake of 660 students. It also offers Master's program of M.Tech. in CSE, ME, ECE and EEE and also MCA and MBA. The college is affiliated to JNTU, Kakinada. The college maintains state-of the-art infrastructure with which it motivates the students to contribute their skills to the society. Another great feather in its cap is it is accredited by the National Board of Accreditation in 2007 and it got ISO 9000: 2009 certification.

About Prof. S. Minakshisundaram Memorial Society

Professor S. Minakshi Sundaram (1913-1968) was a distinguished Professor of Mathematics of Twentieth Century whose contributions to the development and teaching of Pure and Applied Mathematics are highly significant. Known fondly as Prof. S.M.S., he started his academic career in the Department of Mathematical Physics(now called Applied Mathematics) in 1943 at Andhra University, Waltair. From 1962, he served with distinction, the Department of Mathematics there at Guntur P.G. Centre as special officer. He was a great researcher, who published large number of research papers in Journals of high repute. He authored the classical book "Typical Means" jointly with Prof. Chandrasekharan of T.I.F.R. which held him in high esteem world over in Mathematical circles. Prof. S.M.S. is acclaimed to be the most gifted mathematician of his generation. A part of his early work was so great that it influenced the refinement of the famous **Atiyah-Singer Index Theorem,** one of the greatest theorems of twentieth century. Apart from being a great researcher he was a great Guru, who influenced a large number of students both in Mathematics and Applied Mathematics. Many of his associates and students contributed their might in the development of Mathematics as well as in several walks of life.

Some of the admirers and students of Prof. Minakshi Sundaram joined together and with a view to perpetuate the memory of this great teacher and researcher for the posterity, have firmed the society named "Prof. S. Minakshi Sundaram Memorial Society". The society was inaugurated at NIT, Warangal on 22nd October, 2010.

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Ex-Vice Chancellor,
Dravidian University,
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Prof. S. MINAKSHI SUNDARAM - A BRIEF PROFILE

Prof. P. V. ARUNACHALAM,
Retd. Prof. of Mathematics, S.V.U., Tirupathi
Former Vice Chancellor, Dravidian University, Kuppam

Subramiah Minakshisundaram was born on 12th October 1913 in Trichur, Kerala State, of India. He studied in C.R.C.High School, Perambur, Madras State from 3rd Class to Sixth during 1919 to 1929 when he passed S.S.L.C. He had constantly topped in Mathematics having shown a marked aptitude for the subject..

Collegiate Education: Studied Intermediate in Pachiyappa's College, Madras from 1929 to 1931.

Higher Education: Studied B.A. Hons. Mathematics from Loyola College, Madras from 1931 to 1934 and secured First Class First. Got his M.A. Degree in Mathematics of the Madras University on payment of a token sum as was the custom in some universities in India , those days.

Research Work after M.A. : His teachers were the well known Prof.K.Anand Rau and Prof. R. Vaidyanathaswamy . For a few years he worked under R.Vaidyanathaswamy. After studying the books " Mathoden der Mathematics Physik " of Prof. Richard Courant and Prof.Lichtenstein, then Prof.Razaiuddin Siddiqui author of Lectures on Quantum Mechanics and former Professor of Osmania University and who worked under Prof. Werner Heisenberg of Germany he published a few papers in Non-Linear Parabolic Equations.

His thesis was entitled "Fourier Ansatz and Non- Linear Parabolic Equations." Some of his papers were published in the Proceedings of the Indian Academy of Sciences while most of them appeared in the Journal of the Indian Mathematical Society. The thesis as a whole was published by the Madras University in their Journal.

In the year 1940 he was awarded the D.Sc. in Mathematics of the Madras University, its distinguished alumnus, the much coveted degree of those days of a reputed university. For some

time he was Research Fellow, Department of Mathematics of the Madras University on a meager sum.

For a long time he was without any financial assistance and during that period he eked out his livelihood by private tuitions . Dr.P.K.Menon, Director , Joint Cipher Bureau, New Delhi mention that the active Mathematician of Madras that he was in those days and the name he made for himself in mathematical circles of Madras. He was and active member and was primarily responsible for organising a mainature Mathematics Club at Madras , of which Prof.C.T.Rajagopal, Prof.K.Chandrasekharan, Prof.K.G.Ramanathan and few others were active participants. His work attracted the attention of stalwarts in the field of Partial Differential Equations at that time, one of them being Dr.Richard Courant , Professor Emeritus , Courant Institute of Mathematical Sciences, New York University. The report on his thesis was excellent and it was praised very much. His thesis was adjudged to be one of the best thesis for the year 1940 and awarded the Narsinga Rao Medal and also he was awarded the Ramanujam Medal.

Prof.Minakshisundaram could not secure a job in those difficult days in spite of his academic distinctions. Late Prof.Narsinga Rao promised him the job of a Tutor in Mathematics at the Annamalia University, Annamalainagar when he was the Head of the Department of Mathematics there. But in 1943 , when the Department of Mathematical Physics was started by the University at the initiative of late Dr. C.R.Reddy, an eminent educationist, and under the Headship of Prof.Nagendra Nath, Minakshisundaram was offered the post of Lecturer in the Department of Mathematical Physics by Dr.. C.R.Reddy who was very much impressed with his academic achievements.Thus he joined the Andhra University Department of Mathematical Physics as lecturer in the year 1943.

From 1943 to 1946 he worked as Lecturer in the Department of Mathematical Physics in the Andhra University. In 1946 he was invited by the Director , Dr.Aydelotte, to be a Member of the School of Mathematics of the Institute of Advanced Study, Princeton, New Jersey, USA. He was there from 1946 to 1948. Meanwhile the Andhra University Authorities promoted him to Readership in the Department of Mathematical Physics. He worked as Reader in the Department from 1946 to 1950. Late Prof.A.Narsinga Rao was then Head of the Department of Mathematical

Physics having come over from Annamalai University at the invitation of late Dr.C.R.Reddy, Vice Chancellor.

Returning from the Institute of Advanced Study, Princeton, in 1948, he rejoined duty as Reader in the Department of Mathematical Physics, Andhra University and continued in the post till he became Professor and Head of the Department of Mathematical Physics in the year 1951, after the post became vacant due to the retirement of Prof.A.Narsinga Rao in the year 1950.

A significant event in Prof.Minakshisundaram"s career as a Mathematician during 1950 was the invitation to the International Symposium on Differential Equations, Stillwater, Oaklahoma, USA. His participation in the deliberations of the International Congress of Mathematics held at Cambridge, Massachussets, USA , at invitation of the congress. He was the Head of the Department of Mathematical Physics from 1951 to 1962.During this period he worked hard in bringing the reputation of the Department of Mathematical Physics to limelight and a measure of respectability for the students of the department elsewhere in learned Institutions of the world.

In 1958 He was invited on an Educational Tour to USA. as a member of the General Education Team. He was also invited to the International Congress of Mathematicians, Edinburgh, to deliver lecture. This lecture was well received and praised. Dr.M.H.Stone visited the Department of Mathematical Physics and was the guest of honor at a valedictory function of the Departmental Association. It was all due to the personality of Prof.S.Minakshisundaram as a reputed Mathematician. A couple of his students misunderstood him as the path to modern research is difficult. He used to point out his achievemnts as coming from his own hard work and in this none was his guide.

In a sense late Prof.K.Ananda Rau and Prof.R.Vaidanathaswamy appeared to be his guides in disguise when he was confronted with difficulties in his mathematical labors.

In the year 1951, he participated in a summer seminar organized at the Tata Institute of Fundamental Research,Bombay along with his students, now Prof.P.Sambasiva Rao of the Department of Engineering Mathematics of the Andhra University, at the invitation of Prof.K.Chandrasekharan.During that period there was close collaboration between the two eminent

Mathematicians which resulted in their book " Typical Means " seeing the light of day. It was very well received by Mathematicians the world over. It is a source book for further work which the authors have taken pains to compose.

He was very social and had many friends in all ranks of the University Staff and elsewhere. There was none who did not know Prof. Minakshisundaram for generations and generations of students, colleagues and administrative personnel. In a sense he was an idealist, and often at times used to live in a world of his own, always dreamy and always thoughtful, thinking over some problem mathematical or otherwise. Mrs.Minakshisundaram had to take a lot of pains to remind him of his food and other small human requirements of daily life. He had an eye for talent and ability and wherever it was found he used to enslave himself for them. Most of the young talented students were his great friends and he used to derive aesthetic pleasure in their company. He trained a number of students for various examinations and many of them now occupy positions of responsibility in various walks of life.

In 1967 SMS was invited to the Indian Institute Of Advanced Studies in Simla.He was very happy.He never felt happy just teaching and the academic value of the subject was not his forte.In the wonderful surroundings,atmosphere of the foot hills of the Himalayan rangehe could work peacefully and with verve.The last work of his life began.He was once again invited by the then Vice Chancellor Prof. K.R.Srinivasa Iyengar to be the first Director and later Principal of the Post Graduate Center of the Andhra university at Guntur. As Prof.S.Minakshisundaram had a soft corner for Andhra University he relinquished his post at Simla and rejoined the University.

He occupied himself both day and night in organising the Center in various ways which shortened his life as is seen from his premature death through heart disease due to overwork. He had a severe heart attack at Guntur and had to retire prematurely from service of the University much to his regret and those of his admirers. While at Guntur he was offered a Research Professorship in Mathematics at the Institute for Fluid Dynamics and Applied Mathematics, College Park, University of Maryland, USA on a very high salary and attractive terms in recognition of his unusual talents and abilities. Unfortunately, he could not avail himself of the opportunity because of his bad health at that time. His name was proposed for the post of President of the Indian

Mathematical Society, a unique academic honor, but we could not see him function as President of the Society.

He was also selected as Research professor in Mathematics under the U.G.C. scheme for Retired Professors in India. But even this opportunity was denied by cruel Fate which took away his precious life quite unexpectedly. He had a panoramic plan of publishing a number of books on advanced mathematics and it should be mentioned that his premature death was a great loss to Indian Mathematics.

BOOKS PUBLISHED.

1. TYPICAL MEANS S.Minakshisundaram and K.Chandrasekharan . Oxford University Press-Bombay 1952-Fundamental Research Monograms.
2. Lectures on Functional Analysis and Applications. Lectures delivered in I.I.T. Madras, 1965.
3. Composite Mathematics Text in Telugu for students of the VIII Class , Government of Andhra Pradesh Publication and Editor, 1968.
4. SPECTRAL THEORY OF DIFFERENTIAL OPERATORS-HEAT EQUATION. Under Security for possible publication in the Higher Mathematics Series of the Von Nostrand Company, U.S.A.

POSITIONS HELD IN ANDHRA UNIVERSITY.

1. Joined the Faculty as Lecturer in 1943 of the Mathematical Physics Department.
2. Reader in the Mathematical Physics Department from 1946 to 1950.
3. Professor and Head of Mathematical Physics Department from 1951 to 1961.
4. Warden of the University Hostels in 1957 and again 1962.
5. Librarian of the University Library from 1960 to 1961.
6. In Charge Registrar of the Andhra University in 1961.
7. Research Professor in Indian Institute of Advanced Studies, Simla 1966 to 1967.
8. First Special Officer , Post Graduate Center, Guntur, 1967 to 1968. 9. He organized the Indian Mathematical Society Conference at Andhra University in 1961.
10. He gave Special Lectures Seminars during his distinguished career at And University from 1948 to 1966.

SALUTATIONS TO AN ILLUSTRIOUS GURU

V. VANIPRASADA RAO, PRESIDENT

GURUR BRAHMA GURUR VISHNU GURUR DEVO MAHESHWARAHA
GURUR SAAKSHAT PARA BRAHMA TASMAI SREE GURAVE NAMAHA

Guru is verily the representative of Brahma, Vishnu and Shiva. He creates, sustains knowledge and destroys the weeds of ignorance. I salute such a Guru.

According to our scriptures, the Guru is considered on par with the three deities - Brahma, Vishnu and Maheshwara. He is also equal to "Para Brahma" , the Source of the Trinity.

Hindu Mythology says that Brahma, who creates the world and all the beings in it, records on the forehead of every creature the future course of their life. Similarly, a Guru imparts knowledge in the minds of every student and shapes the destinies of their future life. Thus the Guru creates the students.

Vishnu protects and preserves the Universe. He is responsible for each being to achieve its best. In a similar way, the Guru helps students achieve their aspirations. The Guru is deeply interested in his students overall well-being and extends a helping hand. Thus, the Guru fosters and nurtures the students.

Maheshwara or Shiva is a Liberator of people and Guru is Liberator of ignorance in the students. He kindles the real thirst for knowledge in the students and removes all obstacles. Thus, the Guru destroys all ignorance in the students.

Prof. S. Minakshi Sundaram - fondly known as Prof. SMS - possessed all these qualities and embodied the traditional values of a Guru. He was an ideal Acharya who dedicated his life to learning, research and teaching. He was an absorbing teacher with a deep involvement in the topic he was teaching.

Prof. SMS was a dedicated Guru who produced a number of students of high caliber who have held positions of high responsibility in various walks of life in India and abroad. Some are in Academics working as Professors in different Universities In USA and other countries, some are in Colleges and institutes of high repute like IITs, CITs, IIMs, ISI, ISRO etc. Some are in leading organizations in the IT industry, some others in All India Services, the Defense Services etc. It is a great tribute to the Guru and his blessing that one of his students has risen to the level of Nobel Laureate.

Prof. SMS commands high respect not only in academic circles and amongst his students but has many admirers in all walks of life. In his address to the International Congress of Mathematics 2010 held in Hyderabad, the Honorable Chief Minister of Andhra Pradesh Sri K. Rosaiah applauded four mathematicians for their remarkable contribution to Mathematics and one of them was Prof. Minakshi Sundaram. His memory shall live eternally through his contributions to Mathematics and the many students he has trained and who have had distinguished careers with many achievements.

It is my privilege and honor to have had the good fortune to be one of the students of this Illustrious Guru.

With a view to pay homage to the Illustrious Guru, his students and admirers of Mathematics celebrated Prof. SMS's 97th birthday with a Seminar on `Challenges in Current Mathematics Research ` in collaboration with the National Institute of Technology - Department of Mathematics, Warangal on 22nd October 2010 in their Institute. The program was a grand success. The participants felt very happy and expressed their gratitude to the host namely NIT, Warangal and the faculty members of the Department of Mathematics.

Prof. SMS Memorial Society feels grateful to the Prasad V Potluri Siddhartha Institute of Technology (PVPSIT), Vijayawada who have offered to host and organize the Second Annual Meet of the Society with a Seminar on `Current Trends in Mathematical Modeling` on 22nd October, 2011 and release a Souvenir on this occasion.

Eminent Mathematician of India

T.S.G. Krishna Murthy
Professor of Applied Mathematics (Retd)
Andhra University, Visakhapatnam

I was a student of the very first of a three year B. Sc (Honours) course in Mathematics, which was started in 1943, and which was initially a part of the Physics Department of Andhra University, then headed by Prof. S. Bhagavantam. This course precedes a one year M. Sc course by research, in Mathematical Physics.

Dr. S. Minakshisundaram joined this department in 1943 as a lecturer, and taught us analysis for all the three years of our course, and a few topics of the methods of Mathematical physics based on the text book written by Courant and Hilbert..

Dr. S. Minakshisundaram before joining the university at Waltair, worked as a Tutor in Mathematics at Loyola Collage, Madras, at the instance of Fr. C. Rancine. Perhaps, he might have taught subsidiary mathematics to the B. Sc (Honours) Chemistry students during their first year of study, as the chemistry department of Andhra University was partly working in the Presidency College, Madras; and the A.C. College, Guntur (A.P) during 1942-1946.

Inspired by the researches of Prof. M. R. Siddiqui of Osmania University, Hyderabad (A.P); Dr. S. Minakshisundaram was spending a lot of time and energy on the study of partial differential equations, eigen function expansions and the boundary value problems.

His work on “Fourier Ansatz and the non-linear parabolic equations” enabled him to secure the doctorate degree (D.Sc) in mathematics from the Madras University in 1940. His stay in Madras brought him, academically, into a close contact with Prof. K. Ananda Rao of the Presidency College. In those days, Prof. K. Ananda Rao and Dr. R. Vidhyanathaswamy of the Madras University were the most respected and the gifted sources of inspiration for the young interested students of mathematics.

Along with Dr. K. Chandrasekaran of T.I.F.R; Bombay, Dr. S. Minakshisundaram wrote a book entitled “Typical Means”, which was published by the Oxford University press in 1952. This book, I understand, deals with the various topics about which I am not at all component to comment, as I have some limitations to adjudge the scope and the readability of the book.

Dr. S. Minakshisundaram left for USA to spend two years (1946-1948) at the prestigious Advanced Institute of Mathematics, Princeton. By the time, he went to the Institute, Prof. Albert Einstein and Prof. Robert Oppenheimer were also there. The Director Dr. Aydelotte invited him. Later in 1950 Dr. Oppenheimer was the Director and he invited SMS again.

This period (1946-1948) of Dr. S. Minakshisundaram at Princeton must have been an extremely fruitful period, academically, in his life. After Dr. S. Minakshisundaram left for Princeton, I was appointed as a tutor in 1946 in the Department of Mathematical Physics of Andhra University.

Dr. S. Minakshisundaram was awarded, in 1942, the “Ramanujan Memorial Prize” by the Madras University for his research contributions in respective fields and recognition for the outstanding research work.

When the Andhra University Engineering College was started in 1955, Prof. S. Minakshisundaram and I initiated teaching mathematics to the first year B.E. students. I always liked teaching subjects having orientation in Mathematical Physics or Applied Mathematics. Prof S. Minakshisundaram was always appreciating my teaching abilities.

Prof. S. Minakshisundaram praised my research work. Even though, Prof. T.Venkatarayudu and Prof. S. Minakshisundaram belonged to two different schools of thought academically. Prof. S. Minakshisundaram always liked me very much for my other administrative duties, like the deputy wardenship under him, during 1961-1962.

The department of Mathematical Physics of Andhra University was extremely fortunate in having two such eminent personalities at the top of its teaching staff.

After the death of Prof. V. Ramaswamy, Prof. S. Minakshisundaram was transferred as the Head of the Department Mathematics in 1961.

During his excellent period of research and when he was middle age, Prof. S. Minakshisundaram was one of the top mathematicians of this country. He trained several students for their doctorate degrees in mathematics. As I was also his student, this is the best compliment and tribute, I pay him.

Prof. S. Minakshisundaram spent, as a Research Professor for more than a year in 1966, at the newly formed Institute of Advanced Study in Simla.

During 1967, Prof. S. Minakshisundaram worked as a special officer at the Andhra University Post Graduate Centre, Guntur. During this period, his health deteriorated. He got back from Guntur to Visakhapatnam, but survived only for a few months. After a prolonged illness, he passed away in August, 1968, leaving his family in deep distress and with modest means financially.

May his soul rest in peace

A TRIBUTE TO PROFESSOR MINAKSHISUNDARAM

PROF. K. LAKSHMI DEVI
Professor of English (Retd,)
Andhra University, Visakhapatnam

I feel privileged to have been asked to write a few words about Prof. Minakshisundaram, some one I greatly admire and respect. I appreciate the efforts put in by friends, admirers, family members, particularly to bring out a fitting tribute on the occasion of the birth centenary of the Professor.

My own interaction with Professor Minakshisundaram was of a limited nature as I knew him only as an affable, next-door neighbour. I belonged to the Arts Stream (English Literature Honours) and had little to do with the Science Faculty. However, from the campus grape-vine I heard about the academic brilliance of the professor and of his enviable reputation as a fine teacher and researcher. I had joined the house-hold of Prof. K. V. Gopalaswamy, (the then Registrar) as a young daughter-in-law way back in 1956. The two families were neighbours as well as close friends. Those were days when we could afford to be informal and spontaneous in our relationships. Members of both of our families could walk into each others' houses without so much as 'by your leave' half-a-dozen times a day. We were always sure of a warm welcome. Every time I stepped into Professor Minakshisundaram house, I would be greeted with a wide smile from the Professor. Invariable, I would find him sitting cross- legged on a chair at the dining table engrossed in his reading.

The Andhra University in those days was passing through a glorious phase. The first generation of eminent teachers, such as Professor Saileswar Sen, Prof. Bhagavantham, Prof. Sehadri, 'et.al' was succeeded by equally brilliant academicians like Prof. K. R. Srinivasa Iyengar, Prof. R. Venkata Raman, Prof. Kunhan Raja (to name only few). Prof. Minakshisundaram belonged to that elite group though he was much younger than most of them. It was a golden decade of all-round excellence. There was a distinct intellectual aura pervading the university fostered by the men at the helm of administration such as the founding vice-chancellor Dr. C. R.

Reddy, Dr. Radha Krishnan and Dr. V.S. Krishna. The families of both teaching and non-teaching staff and students lived on the campus. They had ample opportunities to mingle and interact with one another, as the campus offered rich and varied cultural experience. Teachers and their families, students in their thousands attended lectures by men in public life, enjoyed plays, music concerts and dance performances. The campus folk were like one big close-knit family.

The departure of Prof. Minakshisundaram to take up a new responsibility as special officer of the newly created post-graduate centre (later to become Nagarjuna University) left a void in our lives. We were elated to hear the news that Professor Minakshisundaram was offered a Research professorship at the prestigious Maryland University of USA. The sudden heart-attack and demise shortly after, left us stunned. The world of mathematics lost a brilliant teacher. My husband, Prof. Venkata Reddy and I cherish our memories of Prof. Minakshisundaram and of his family. Our lives were enriched by the friendship of Professor Minakshisundaram's entire family.

RECOLLECTIONS OF PROF.S. MINAKSHISUNDARAM

Dr. R.K. SHARMA, CALIFORNIA,USA

I first heard about Prof. S. Minakshisundaram when I was trying to decide about what to do after finishing Junior college at the Loyola College, Madras. The options I was considering were Engineering Physics and Mathematics. My father wanted me to go into engineering as he was a civil engineer and felt that engineering would be a good career for me also. I could not get into engineering at Madras because I was born in Mysore and at Bangalore because I was domiciled in Madras.

My mother wanted me to go into law after a basic degree in the liberal arts or the sciences because many of her relatives were successful lawyers who had a good life without having to leave Madras, unlike my father who spent most of his time in remote areas!

I decided to go into the sciences, but I still had to decide what science. I liked physics, but I didn't enjoy writing lab reports! I actually joined B.A (Honors) in Mathematics at Loyola College. At this point, my uncle, Sri S.T. Krishnamachari who was a reader in French and German at Andhra University told me about a brilliant professor at Andhra University who was teaching mathematical physics and worked with many leading scientists at Princeton in the USA. This was exciting news because I could study physics without having to write lab reports! (As it turned out, however, I had to write lab reports for one class at Andhra University also!)

So, I went to Andhra University and studied mathematical physics. Prof S. Minakshisundaram introduced me to real and complex analysis (Hardy, Goursat) Calculus (Courant) methods of mathematical physics (Courant and Hilbert), theoretical physics (Joos) et. He was an inspiring teacher and inculcated a love of mathematics in me.

However, after my B. Sc (Honours) I opted to study Electrical Engineering at the Indian Institute of Science, Bangalore, even though Prof. S. Minakshisundaram offered to help me to go to the USA for higher studies in mathematical physics. My parents were not willing to let me go abroad at that time and I became one of Prof. S. Minakshisundaram students who did not pursue research in mathematics.

But the love of Mathematics instilled in me by Prof. S. Minakshisundaram helped me considerably in successfully completing the M.S. at UC. Berkeley and Ph.D at UC., Invine, US (both in Electrical Engineering) many years later.

I came to know Prof. S. Minakshisundaram as a neighbor also, as he lived next door to my uncle. I came to know his family also well. I was fascinated by his absorption with Research. Prof. S. Minakshisundaram used to sit in the verandah for hours at a stretch, smoking away and doing his research. He was a chain smoker at that time, holding the cigarette between the third and fourth finger of his left hand, closing the hand at the bottom with the fore and little fingers inhaling through an opening formed by the thumb, for and middle fingers at the top. Dr S. Minakshisundaram was a kind, friendly and helpful person. He used to relax by playing bridge with friends at home or at the faculty club nearby. He will be remembered by mathematicians in India and abroad for his many contributions to mathematics.

Consciousness - What is it?

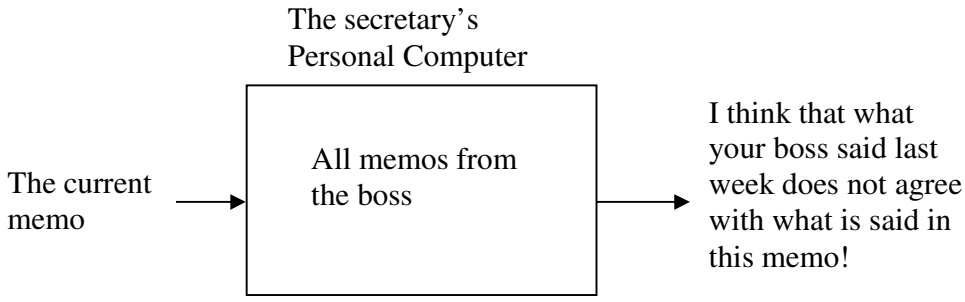
Prof. Syamala Hari
New Jersey , USA

In honor of the memory of our beloved Late Professor Minakshi Sundaram garu, I wish to share with the seminar participants, a few ideas that I have been working with in a scientific study of consciousness, which is my current area of interest. Modern scientists involved with this field often use quantum theory for their research. As every theoretical physicist knows, theories of Hilbert spaces, function spaces, linear and non-linear partial differential equations, integral equations, boundary value problems, and Fourier analysis, are the backbone of quantum formalism. The invaluable contributions of our Mastergaru in all the above areas (and other areas as well) are only too well-known and too many. When our Mastergaru taught any of these subjects in a class, he used to bring out the intuitive aspects (rather than simply writing and deriving mathematical equations on the board) of how the simple theory of linear algebra in finite dimensional vector spaces can be and is generalized to the various theories such as Hilbert spaces, differential and integral equations, and so on. Thus, his style of teaching developed intuitive and research-prone thinking in the student and made the student feel that mathematics is interesting after all, but not an abstract and dry subject. After I left India, I worked as a system engineer in telecommunications corporations, and for a long time, had nothing to do with the mathematics I had learned, and therefore forgot it all. Now that I am interested in the quantum theory of consciousness, I am beginning to recall what I was taught by Professor SMS and other teachers who were all his students one time or another.

I was drawn to the study of consciousness by working with computers which made me wonder whether there is anything that we, human beings are capable of but computers are not. Of course, the answer is simple: human beings are conscious but not computers; is it not so? No, not so quickly; there are many computer scientists who are ready to fight with those who give the above answer. Those computer scientists strongly believe that the days when we see conscious computers are not far off! Yet, to build a conscious computer, or to explain by means of physics or neuroscience, why consciousness is present in a living brain but not in lifeless matter, one has to

first of all, understand what consciousness is. That is not at all easy as we shall see here even without getting into any quantum theoretical aspects of the investigation.

We say that rocks (and all other lifeless things) are not conscious. We think that birds, animals, and other living beings have various degrees of intelligence and of course, that a human being is more intelligent than all the other species because for example, people do arithmetic whereas animals usually cannot. Interestingly, our packet calculators can do arithmetic always accurately and much faster than we but we do not think they are intelligent or conscious. At the same time, if a person does arithmetic like a calculator (and we hear about such people once in a while), he/she would be called a genius! Do we know what we mean by intelligence or consciousness? One who is enjoying a sight of birds flying over the quiet waters of a lake may admire them saying "how full of life these little birds are" (probably because a dead bird cannot fly) but clearly, flying is not something that distinguishes life from lifeless matter, an airplane can fly much faster. In this age of robots, we cannot be sure that a bird's ability to fly on its own whenever it wants to and not needing a human pilot to fly it, is evidence that birds have some intelligence but not airplanes because aircraft do not need human pilots either. The so called drones have computers in them and fly in enemy territories without human pilots. Nowadays, machines can see, hear, talk, walk, and even think; they can solve mathematical problems! Herbert Simon's statement that there are no discernible limits to the range of things which computers can be programmed to do has come true. A computer, our personal computer (PC) for example, can exhibit some intelligent behaviors like human beings whereas a simple typewriter cannot although both the typewriter and the PC (of today) are not conscious. For example, the PC can tell that an earlier memo from the boss is inconsistent with the one typed into it now; the typewriter cannot do that. The PC has this capability because it is equipped with a memory with some contents called software. When we key letters into a typewriter, it responds by hitting the paper, types the letters on the paper and they are saved there. The PC on the other hand, has a memory where it stores not only the letters recently typed but also other data and software instructions which are all already entered into it earlier. When a 'return' character is input, it starts the process of executing the software which performs various intelligent tasks. Note that neither the typewriter that types a memo on the paper, nor the paper which contains the memo, nor the PC into which the same memo is entered understand the contents of the memo but the PC can judge the contents of the memo like we do!



We are able to prepare the PC to pretend such intelligence because information residing in our brains (at least some of it) can be mapped into languages, and then words can be mapped into some physical material (hardware) units, and therefore mappings of information (from the brain) can be stored in the PC's memory. The PC is then able to carry out all the operations of receiving, storing, retrieving, and processing and act as though it understands its memory contents but it does not. So, to remember something is not consciousness; a machine can remember something without understanding what it means! Nor does arguing logically require consciousness because again, a machine can do it! On the other hand, unlike the computer, the brain understands its memory contents, at least some of them or to some degree; that is what we think anyway (the answer to "do I know myself " is "yes and no"!). Of course, the physical apparatus and the memory structure of the brain and the computer are entirely different. Some brain scientists say that this feeling of understanding, knowing, or consciousness is a macroscopic and cumulative effect of neuron activity just like temperature is the macroscopic effect of particle dynamics at the microscopic level. Although this explanation sounds reasonable, it implies that a human being's consciousness disappears when the neural activity ceases (the brain dies). The implication is not consistent with what eastern philosophies (and probably Christian philosophies too) say namely that "spiritual" stuff survives when the physical body dies. This stuff includes the so called "Consciousness" (with big C in the front) and the so called soul. All theist religions believe in the existence of a God who is conscious all the time. A difference between Consciousness and the human consciousness is that the former is eternal and uninterrupted whereas the latter comes and goes. Living beings are conscious when they are awake and not in deep sleep and their consciousness is limited in other ways unlike God's Consciousness according to any religion. The soul is supposed to be conscious also because again, all religions who believe in the existence of a soul talk about the soul's being happy in the heaven or being miserable in hell. The soul is individualistic; there are many souls whereas Consciousness is just one and not fragmented. The area of major conflict between

scientists and spiritualists is this spiritual stuff. What about emotions, anger, joy, envy, passion, etc.? They seem like they are part of human consciousness and lifeless objects do not seem to have emotions. A chess playing program may play chess very intelligently but it does not care a bit about winning or losing (like one of those enlightened sages!). That is so because the program does not have the desire to win the game to begin with. An emotion occurs as a response to fulfillment or non-fulfillment of some desire or the anticipation of fulfillment or non-fulfillment of a desire and obviously, lifeless objects do not have desires. Are desires part of consciousness? They are certainly part of our memory but are they the source of consciousness? It seems reasonable to assume that one can be conscious without any desire. There can be wakeful moments in our lives for example, while watching animals in a zoo, when we do not think about any of our desires. Hence it seems that one can be aware of one's desires or any other thoughts or experiences, which are all contents of one's memory, when one pays attention to them; the memory contents are objects of awareness but they are not the same as the ability to be aware. If desire, thought, emotion, experience, etc. are not consciousness and if they do not exist in pure lifeless matter, religion or no religion, what is the ability of human beings to be conscious due to, which lifeless matter does not have? Note that the computer can exhibit, that is, pretend to have all the above mentioned features of human consciousness; for example, it plays to win the chess game without any desire to win. Then there is the ability of human beings to make choices and decisions and usually called free will. But again, there are decision-making computer programs also. To make a decision, a program depends upon some rules stored in the computer memory and strictly follows them to arrive at the decision; the program never violates any stored instruction. So also, a human being's decisions and choices depend upon his/her memory because the decisions almost always depend upon desires, ambitions, goals, etc. all of which expect some benefits in the future and all of which are stored in the memory. Such a decision is mechanical in the sense that a machine can also make it. We usually call a decision or a choice as a free one if it is in accordance with our wishes but not against our wishes. A machine can make such decisions if descriptions of those wishes are entered into its memory. So, the ability to make decisions and choices does not require consciousness! However, like before, it seems reasonable to assume that a human being has the ability to make a decision without depending upon any beliefs, convictions, and experiences, in other words not depending upon any memories of the past, nor expecting any benefit in return (free will not subject to causality). If we assume that such free will exists, then it must be all pervading and everlasting because such free will is "free" from all laws and limitations

including those of space and time. Such free will is the universal consciousness that spiritualists talk about. It may not be possible to explain in scientific terms such free will which is not subject to causality because science is based on logical theories and experimental verifications, in other words, based on principles of causality. So, what is consciousness anyway? Is it memory? Is it logic? Is it desires? Is it emotions, is it thoughts? Is it free will? Is it all of those? Or, none of them?

AN APPLICATION OF ACYCLIC SETS TO BUS SCHEDULING PROBLEM

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ABSTRACT

A method or concept developed specifically to solve a particular real life problem will be sometimes exploited to solve another problem which occurs in an entirely different field. For example, the results of divergent series were successfully used in discovering the atom bomb. The state space approach developed in connection with problems in control systems theory is now-a days being employed successfully to solve a certain class of problems in fluid dynamics. Sometimes mathematicians develop concepts out of mathematical curiosity, though not motivated by any real world problem. Some ideas and operations developed in purely mathematical way, for example in Number theory, Boolean Algebra etc. have found highly significant applications in Computer Science, Cryptography etc. While being introduced to the elementary idea of relations in mathematics, one may not appreciate any great significance attached to the concept. As one learns more and more, it is likely that one will appreciate the possible utilitarian value of the concepts studied or may just appreciate the beauty of the mathematical development of the topic under consideration.

The elementary ideas related to an acyclic set and its decomposition into a set of disjoint chains when looked at from a pure mathematician's angle have an aesthetic appeal of their own. The aim of the talk is to present an application of these ideas in solving a real world problem of bus scheduling wherein a number of prescribed bus trips are to be performed by using minimum number of buses. The problem will be related to a 0-1 linear programming problem as well. How a large sized bus scheduling problem can be tackled will be presented.

INTRODUCTION

The problems wherein we seek to maximize or minimize a certain objective function depending on a number of variables satisfying some constraints are in general termed as optimization problems. For quite sometime, such problems were encountered in physical sciences and geometry and researchers' quest for solutions led to the application and development of calculus and calculus of variations.

The post second world war period has changed the scenario. Several optimization problems in various disciplines, other than physical sciences (and including these as well) were identified, which are not amenable for treatment through calculus methods. There arose opportunities to create several new solution techniques to suite special types of problems such as linear

programming problems, integer programming problems, nonlinear programming problems, transportation problem, transshipment problem, network flow problems etc. Some of these techniques which were designed for specific purposes, were suitable to solve problems in other contexts also. For example , the labeling algorithm developed by Ford and Fulkerson for solving the network flow problems has found on application in *decomposing an acyclic set into minimum number of disjoint chains.* The problem of decomposing an acyclic set into minimum number of disjoint chains appears to be a mathematical problem that arises in algebra. How ever , it is interesting to note that this problem arises in a natural way in the problem of bus-scheduling. This talk is aimed at discussing the problem of bus scheduling with reference to a Road Transport Corporation which has many divisions or depots under its control and which aims to run minimum number of buses to cover all the trips on hand. How this problem can be viewed as the problem of decomposition of an acyclic set into minimum number of disjoint chains, will be explained.

BUS SCHEDULING PROBLEM

Consider a Road Transport Corporation which has several divisions or depots under its control. Each division operates a number of buses. One of the important tasks of the corporation in general, is the preparation of time tables periodically. For this,one has to assess the demand for the passenger buses, the load factor etc., and arrive at a list of trips to be operated by the corporation. A trip is a journey performed by a bus between two places, starting place and ending place during a specified time period characterized by a starting time and ending time. The list of trips consists of the starting place, the ending place , the starting time and the ending time concerning each trip. It is to be noted that the number of trips and the timings do not remain the same over the entire year. These fluctuate with the varying demand over the seasons. The corporation increases or decreases the frequency of the trips on the existing routes or append or delete some (new) routes to meet the volume of traffic and the needs, depending on the feasibility. Thus the preparation of a time table is a job which is to be taken up periodically.

Once the trips in each route are decided, the corporation makes a schedule indicating which bus should cover which trip and so on. In other words, the trips are grouped in such away that each group of trips can be operated by a single bus. If possible, this grouping must also be done in such a way that the bus requirement and crew requirement are minimized. If the number of trips involved, the number of divisions involved and the number of personnel involved are all extremely small numbers, this scheduling can be attempted manually. When these numbers are large, to prepare an optimal schedule for the buses and crew to meet the trip requirements, it is ideal to have a scientific approach and mechanize the whole job to get the solution. Suppose , we want to concentrate on the trips to be performed by the buses only. To do this it is necessary to develop an algorithm to group the trips so that each group of trips can be operated by a single bus and at the same time minimize the number of buses required. As mentioned already, this problem can be linked with the problem of decomposition of an acyclic set into minimum number of disjoint chains.

SOME BASIC IDEAS

We know about Relations in real life. Relations in Mathematics are more general. The following ideas are well known.

- *Relation from A to B is a subset of AxB*
- *Relation in a set A is a subset of AxA*
- *Relation R in A is a Partial order relation if the following conditions are satisfied:*

aRa for all a in A (R is reflexive)

For a, b in A, aRb, bRa implies a = b (R is antisymmetric)

For a, b,c in A, aRb, bRc implies aRc (R is ransitive)

In place of R above, let us write ≤. A set on which a partial order relation is defined is called a partially ordered set.

Examples

(1) R = set of reals. R is a partially ordered set w.r.t the usual ≤.

(2) Let A be a non empty set and P be the power set of A*. For A, B in P define*

A ≤ B iff A is a sub set of B. Then P is a partially ordered set w.r.t. ≤

(3) Let P be the set of all positive integers. For a, b in P, define a ≤ b iff a divides b. Then P is a partially ordered set w.r.t. ≤.

Let P be a partially ordered set w.r.t. a relation R. x,y in P are said to be comparable if x R y or y R x.

Chain: If $\{a_i\}$ is in P such that

$a_1 \leq a_2 \leq a_3 \leq a_4 \leq a_5$.....

it is called a chain. Two chains having no elements in common are called disjoint chains.

Two elements in P may or may not be comparable. Suppose in P any two elements are comparable. Then ≤ is called a total ordered relation. If P is a totally ordered set with relation ≤, P is a chain.

DETAILS OF 24 BUS TRIPS

TripNo.	*Start*	*End*	*Start Time*	*End Time*
n	*Ps*	*Pe*	*Ts*	*Te*
1	*A*	*B*	*08.40*	*09.40*
2	*A*	*C*	*10.50*	*11.40*
3	*A*	*C*	*08.25*	*09.15*
4	*A*	*C*	*06.25*	*07.15*
5	*A*	*D*	*09.45*	*11.45*
6	*A*	*C*	*07.00*	*07.50*
7	*A*	*E*	*11.20*	*12.10*
8	*A*	*C*	*15.00*	*15.50*
9	*A*	*E*	*14.00*	*14.50*
10	*A*	*F*	*13.50*	*15.05*
11	*A*	*C*	*16.45*	*17.12*
12	*C*	*A*	*07.25*	*08.15*
13	*C*	*A*	*18.00*	*18.50*
14	*C*	*A*	*09.45*	*10.45*

15	*C*	*A*	*12.00*	*12.50*
16	*C*	*A*	*16.20*	*17.10*
17	*C*	*A*	*08.05*	*08.55*
18	*G*	*A*	*07.25*	*08.15*
19	*B*	*A*	*09.50*	*10.50*
20	*D*	*A*	*11.40*	*13.20*
21	*E*	*H*	*15.05*	*15.55*
22	*E*	*A*	*12.25*	*13.15*
23	*F*	*A*	*15.00*	*16.15*
24	*H*	*G*	*16.15*	*18.30*

Acyclic set:

- *Suppose P is a non empty set endowed with a relation called "Precedence relation".If there is no chain in P whose first and last elements are same, P is said to be an acyclic set.*
- *A set of disjoint chains in P, is called a decomposition of P, If each element of P belongs to a chain in the set.*
- *How to decompose an acyclic set into minimum number of disjoint chains?*

Illustration:

Consider a set consisting of the set of all trips to be executed by a Road Transport company. To illustrate the procedure, we shall consider a set of 24 trips as given earlier between the depots A, B, C etc. Let the set of trips be P = { 1,2,3,4,…….24}. We define a precedence relation on P as below. A trip i is said to precede trip j iff

Ending place of trip i = the starting place of trip j
and Starting time of trip j $\geq$ ending time of trip i + (some r)

With this ($\leq$) Relation of precedence defined on P, P is an acyclic set. It can be proved that this set can be decomposed into 9 disjoint chains. This is the minimum number. The decomposition is given by {B1, B2, B3, B4, B5, B6, B7, B8, B9} where

B1:{12,1}; B2:{4,17,2,16}; B3:{6,14,7,21,24}
B4:{3,15,9}; B5:{19,10}; B6:{20,11};

B7:{22,8,13}; B8:{23}; B9:{18,5};

Consider the chain {6,14,7,21,24}. We notice that $6 \leq 14 \leq 7 \leq 21 \leq 24$ as below.

6	A	C	07.00	07.50
14	C	A	09.45	10.45
7	A	E	11.20	12.10
21	E	H	15.05	15.55
24	H	G	16.15	18.30

A bus which performs trip 6 can later successively perform 14, 7, 21, 24. The other chains can also be understood this way. Ford and Fulkerson Labeling algorithm can be used to decompose the acyclic set into minimum number of disjoint chains. The problem can also be formulated as a 0,1 integer programming problem.

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Our Sincere thanks to

Prof. T.K.V. Iyengar

Mr. B. Punnamchandar

Mr. M. Phani Kumar

and

Mr. M.A Srikanth

for their help in bringing out the souvenir

B.D.C.N. Prasad