PHYSICS IN DEVELOPING COUNTRIES:

Past, Present and Future

Editors
Dr. Hameed A. Khan
Prof. Dr. M.M. Qurashi
Engr. Tajammul Hussain
Mr. Irfan Hayee

April 2006

Commission on Science and Technology for Sustainable Development in the South

8

COMSATS' Series of Publications on Science and Technology

Physics in Developing Countries: Past, Present and Future

Editors

Dr. Hameed A. Khan
Prof. Dr. M. M. Qurashi
Engr. Tajammul Hussain
Mr. Irfan Hayee

April 2006

Commission on Science and Technology for Sustainable Development in the South

COMSATS Headquarters
4th Floor, Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad.
Ph: (+92-51) 9214515-7, Fax: (+92-51) 9216539
URL: http://www.comsats.org.pk, email: comsats@comsats.org.pk

PHYSICS IN DEVELOPING COUNTRIES: PAST, PRESENT AND FUTURE

Editors

Dr. Hameed A. Khan
Prof. Dr. M. M. Qurashi
Engr. Tajammul Hussain
Mr. Irfan Hayee

Published: April 2006

Printed by: *M/s A.R. Printers*

This book is published under the series title *COMSATS' Series of Publications on Science and Technology*, and is number 8th of the series.

Copies of the book may be ordered from :
COMSATS Headquarters
4th floor, Shahrah-e-Jamhuriat
Sector G-5/2, Islamabad, Pakistan
email: comsats@comsats.org.pk
Website: www.comsats.org.pk
Ph: (+92-51) 9214515-7, (+92-51) 9204900
Fax: (+92-51) 9216539

Price: US$ 10 or equivalent

Commission on Science and Technology for Sustainable Development in the South

Physics in Developing Countries: Past, Present and Future

TABLE OF CONTENTS

RESEARCH IN PHYSICS

DEVELOPMENT & TECHNOLOGY

INDEXES

PREFACE

It is a hard reality that the countries of the Third World lag far behind the developed world, primarily due to the absence of well-equipped scientific institutions, universities and facilities. The level of training and research in physics varies remarkably across the world, with the most advanced nations producing far more PhDs in Physics than the developing countries. Realizing this deficiency, it is imperative for the developing countries to have a good-quality system for science-education in place, if they want to grow economically. It is also true that, in the past, individuals made significant discoveries, but now teamwork is essential to achieve that. Presently, useful contributions come mostly from groups of highly educated and skilled individuals who are working on big machines and in centers with huge infrastructure and sophisticated equipment. Today, no single developing country in isolation can accumulate enough experience or infrastructure to cater for its scientific, technological and consequent economic needs. South-South cooperation and, where needed, South-North cooperation are imperative in this regard.

In order to (a) highlight the importance of Physics in development, (b) bring forward the experiences of developed and developing countries in which physicists have contributed towards the growth of the economy, and (c) devise strategic recommendations for promoting Physics and related disciplines for sustainable development, COMSATS organized an International Seminar on Physics in Developing Countries: Past, Present and Future, on July 27-28, 2005, at Islamabad. This seminar was organized in collaboration with the Islamic Educational, Scientific and Cultural Organization (ISESCO). Other objectives of holding this Seminar included enhancing awareness of the potentials of Physics for improving the lives of the people, particularly those of the developing world, and emphasizing the role of international co-operation in Physics and requisite modalities of instituting and promoting South-South and South-North cooperation.

It was a welcome coincidence that the world's physics community was celebrating the International Year of Physics-2005 when this seminar was organized in Islamabad. The objectives of the seminar were closely related to those prescribed by the IYP-2005. As a matter of fact, the present seminar constituted a part of the IYP-2005 celebrations from Pakistan's scientists and turned out to be a useful component of the celebrations of the International Year. A comprehensive compilation in this context has been included in the present proceedings, which describes the genesis of the IYP-2005, the UN support it received, some salient contributions from the physicists of Pakistan,

conclusions, and recommendations. In a way, this analytical review of the IYP-2005 supports and complements several other papers presented in the International Seminar on "Physics in Developing Countries: Past, Present and Future". It is recommended that the reader may like to synchronize the output of this review with those emerging from several other papers included in the current proceedings.

There were a total of 20 speakers in the Seminar who made presentations in 6 Technical Sessions, of which 7 were foreign experts representing the countries of Egypt, Sudan, Sri Lanka, and Tajikistan. Other participants included eminent physicists, heads of S&T institutions, scholars and students from various academic and research institutions. The proceedings of the Seminar include the contents of the presentations made by the speakers and the recommendations that emerged during the various sessions of the seminar.

I would like to express my deep sense of appreciation for Dr. Ishfaq Ahmad, N.I., H.I., S.I., Special Advisor to the Prime Minister of Pakistan, for his guidance, advice and support for this seminar. My gratitude is also due to Dr. Faiq Billal, Director, Islamic, Educational, Scientific and cultural organization (ISESCO), for his ardent cooperation and help in organizing this conference. My earnest praise also for Dr. M.M. Qurashi, Mr. Irfan Hayee, Ms. Zainab Hussain Siddiqui, Ms. Noshin Masud and Mr. Imran Chaudhry from COMSATS whose devotion made publication of the proceedings of this seminar possible.

(Dr. Hameed Ahmed Khan, H.I., S.I.)
Executive Director

FOREWORD

From the pure beauty of general relativity to modern high technology, Physics is a fascinating and worthy subject, leading to both new applications and in-depth observations about the universe. The influence of physics in the enhancement of old technologies and the development of new ones is enormous. Both the methods and the subject-matter of physics are vital to technological development, leading to increased productivity in the economy.

The year 2005 was declared the International Year of Physics (IYP) by the General Assembly of the United Nations Organization. IYP 2005 was a worldwide celebration for physics and its importance. The year 2005 also marked the 100th anniversary of Albert Einstein's three important papers describing ideas that have since influenced all of modern physics. The IYP-2005 provided an opportunity to celebrate Einstein's great ideas, and their influence on our lives in the 21st century.

The celebrations were arranged all over the world. The scientific community of Pakistan, particularly the physicists, took special interest in celebrating the IYP-2005. Academia, researchers, scholars, young science-students and media participated in several activities arranged for this purpose.

COMSATS has played an active role in the celebrations related to the IYP-2005, it arranged and co-sponsored several seminars, symposia, meetings, etc. The present seminar, “Physics in Developing Countries: Past, Present and Future” was a part of these activities.

It is appropriate that the outcome of such an important seminar should be widely disseminated for the benefit of large section of our society. The proceedings of the event will adequately serve this purpose. The seminar, comprising 18 papers on diverse aspects of the title, presented by renowned experts in the respective fields, gives a thought-provoking opportunity to the physicists and policy-makers for devising necessary strategies for a better future of Physics. The areas covered in the proceedings represent, physics education, research in physics, development and technology and, quite appropriately, some historic perspectives. The message emerging from the seminar is clear: that quality of physics teaching and research can be appreciably enhanced by encouragement from the governments, policy-makers and other informed sections of the society. At the world level, the prospects of a better physics would brighten with enhanced international cooperation and through free exchange of knowledge.

I would like to take this opportunity to praise the efforts of Dr. Hameed Ahmed Khan H.I., S.I., and his team who organized this event to enlighten the researchers, businesses and the public about the importance of investment in physics, which can ultimately lead to economic development and an enhanced quality of life.

(Dr. Ishfaq Ahmad, N.I., H.I., S.I.)
Special Advisor to the
Prime Minister of Pakistan

THE INTERNATIONAL YEAR OF PHYSICS – 2005 INCLUDING CONTRIBUTIONS BY THE PHYSICS COMMUNITY OF PAKISTAN

Hasibullah
Advisor (International Affairs), COMSATS Headquarters
Islamabad - Pakistan

ABSTRACT

The worldwide celebrations of the International Year of Physics-2005 have brought tremendous intellectual and scientific benefits to the physics community. The year 2005 was well chosen for this occasion, as it was linked to Einstein's three revolutionary and imaginative scientific papers published in 1905-remembered as Annus Mirabilis (Miraculous Year) by the men of science. These three publications by Einstein gave an entirely new perception to the thinking processes of physicists in the twentieth century and provided the world with inventions that surround our everyday lives with abundance and with inescapable necessities.

The physics community of Pakistan has participated in the celebrations with zeal and joy. The Commission on Science and Technology on Sustainable Development in the South (COMSATS) has taken a leading role in making the occasion a success, in collaboration with the public and private-sector research and teaching institutions. The objectives and purposes of the IYP-2005 did not remain confined to celebrations alone, but went much beyond that. For Pakistan, like many developing countries, it meant taking stock of the stature of physics, its quality, its benefits to the society and creating new opportunities to improve the education and basic research in various disciplines of physics. The most important aspects were the revival of interest in physics by the younger generation of Pakistan enhanced enrolment of female students in physics classes, creation of more conducive environment for careers in physics and public awareness of the potentials of physics in promoting socio-economic development in the country. Like the three revolutionary papers of Einstein a hundred years ago, three of his very appropriate quotes fitting the importance of IYP-2005 and relevant to Pakistan are (i) imagination is more important than knowledge, (ii) science is a wonderful thing if one does not have to earn one's living at it, and (iii) most teachers waste their time by asking questions which are intended to discover what a pupil does not know, whereas the true art of questioning has for its purpose to discover what the pupil knows or is capable of knowing.

These quotes very subtly refer to the three areas where the physics culture of our society needs readjustment, i.e., quality of physics, careers in physics and teaching of physics. It is evident that Einstein's above-stated quotes will provide our physicists with ample food for thought to address our physic's problems.

This article provides a brief description of the relevant activities linked to the IYP-2005, both at international and national level. A description has also been given of the efforts made by Pakistan's physics community to make this important world event a true success. The Article does not give, by any means, a full discourse on all the events that have taken place in Pakistan, simply because that full data was not available in a timely manner. This will hopefully be compensated in a future edition of this book. Conclusions and recommendations have also been included, which were arrived at as a result of close watch on the events marking the celebrations of IYP-2005. It is expected that these conclusions and recommendations will receive due consideration from Pakistan's physics community and the policy makers.

BACKGROUND AND INTRODUCTION

Physics has played a crucial role both in understanding the fundamental laws of nature that govern the universe and in transforming humanity to the present-day "modern living" by harnessing the potential of these laws. Man has been able to conquer the space, the oceans and the lands, mainly with the power of Physics. On the one hand, secrets of the cosmos are being continuously unfolded by this great science and, on the other hand, man is discovering new universes within the profundities of the atom. A lot of this progress has been made in the span of the past few centuries. Physics is now unfolding new vistas of knowledge and bringing additional might within the control of man, with a breathtaking pace and with mind-boggling diversity. If the present pace of advancement in Physics continues, our present-day civilization might appear primitive to our posterity.

But there is a more serious concern also: the coming younger generations of students are seemingly losing interest in basic sciences, including Physics. Diminishing attractiveness in scientific careers, lack of encouragement and support by the governments, prevalence of non-conducive educational and research environment and greater availability of alternative non-scientific opportunities (linked to better social security and job satisfaction) are some of the main reasons for the depletion in the class- room density of Physics students. It is imperative that our society creates and maintains a critical mass of good physicists, in order to ensure a better future for Physics and consequently a better future for humanity.

Creation of public awareness of the importance of Physics for the progress of mankind is also another serious necessity. People read and learn very little about Physics in their everyday life. There is an appreciable shortage of popular literature on Physics. Hardly is there any interesting and comprehensible media-coverage on what is happening about Physics around the world. One may occasionally see some interesting information on physics, meant for the lay-man, on the internet but how many people have access to this facility? The general ignorance about science and especially of Physics is much more prevalent in the underdeveloped world than in the industrialized nations. So, the knowledge-gap in Physics is rapidly increasing between the developing and the developed societies. Social benefits available from the

potentialities of Physics are severely constrained in the developing countries, mainly due to the chronic lack of awareness about this great scientific discipline. Few, if any, would have ever appreciated the extensive and costly fundamental research in Physics that had gone into the commercial production of such commonplace items as transistors, automobiles, electricity, mobile phones, x-ray machines, computers and many more that are now available to give the contemporary world an entirely new perspective of life.

And then there is the cardinal question of moral responsibility of the scientists, physicists inclusive, in the pursuit of their scientific research. Implications of the outcomes of Physics research are by far the most impact producing on the society today than many other disciplines of science. Several world organizations are actively engaged in promoting the concept of Physics for peace and the well-being of humanity. A vast majority of the Physics community is striving to induct the higher norms of ethics into the scientific research and development programmes being carried out around the world. Social acceptance of Physics as a 'benign science' for mankinds' humanitarian service and for the safety of earth's environment is now a common desire of the Physicists working in the laboratories and the educationists in the universities. This is an important aspect for the future progress of Physics and its ensuing `benefits to humanity.

GENESIS OF THE WORLD YEAR OF PHYSICS - 2005

The foregoing ideas and several others have remained in the minds of the conscientious physicists throughout the world for many years. It was, therefore, logical and appropriate for the Physics community to look for an international occasion to highlight and promote the importance of research in Physics, to arouse public awareness, to debate the ethics of the practices of Physics and to discuss the impact of Physics on the social well-being of mankind. Such an occasion was envisioned at the World Congress of Physical Societies in Berlin in December 2000, where more than 40 physical societies from all around the world approved the proposal to declare 2005 as the World Year of Physics because, at the same time, the world scientific community could also commemorate the 100 years of the publication of a series of legendary papers by the most illustrious physicist of modern times, Albert Einstein, who provided in these publications, the basis for three fundamental fields in Physics: the theory of relativity, quantum theory and the theory of Brownian motion. The publications ultimately produced immense impact on the future progress of physics, both basic and applied.

Following the Berlin Conference, the Council of the European Physical Societies agreed in March 2001 to mobilize support in Europe for this initiative. In October 2002, the International Union of Pure and Applied Physics (IUPAP) unanimously adopted a resolution declaring 2005 as the World Year of Physics. The resolution not only provided approval for celebrating "World Year of Physics – 2005", but also laid the foundation of the justifications and the core points which earmarked the need for such

an occasion. These core points were (a) importance of Physics for understanding the nature of the physical world, (b) Physics being the basis of much of today's technology, (c) necessity of Physics education for the developing world to improve their scientific infrastructure, and (d) celebration of 100th anniversary of a series of great scientific advances by Albert Einstein.

Subsequent to the declaration of the IUPAP to celebrate 2005 as the World Year of Physics, a number of international organizations expressed their support for the occasion. This was joined by people all over the world. To coordinate the implementation, representatives of 4 continents and 22 countries met in Graz, Austria, for a three-day conference from 6-9 July 2003 to discuss strategies and ideas for better implementation. Several national and regional meetings took place intermittently for the success of the proposed event.

SUPPORT AT THE UN PLATFORM

The idea of celebrating 2005 as the World Year of Physics also attracted enthusiasm and support of the UNO. The 32nd session of the General Conference of UNESCO adopted, in November 2003, a resolution supporting the initiative. The importance attached by UNESCO to the proposal of the World Year can be realized by the text of the resolution encompassing a large array of the characteristics of Physics, its benefits to mankind and the popular support the proposal had gained all over the world. The resolution adopted states:

i. Recognizing that Physics provides a significant basis for the development of understanding of nature;
ii. Stressing that education in Physics provides women and men with the tools to build the scientific infrastructure essential for development;
iii. Considering that research in Physics and its applications have been and continue to be a major driving force to scientific and technological development, and remain a vital factor in addressing the challenges of the 21st century;
iv. Being aware that the Year 2005 marks the 100th anniversary of a series of great scientific advances by Albert Einstein;
v. Welcomes the resolution of the International Union of Pure and Applied Physics (IUPAP), at the initiative of the European Physical Society, to declare the year 2005 the World Year of Physics and carry out, within its framework, activities to promote Physics at all levels, worldwide;
vi. Decides to support the initiative of the World Year of Physics 2005;
vii. Invites the Director General to request the United Nations General Assembly to declare 2005 the International Year of Physics.

Following the passage of the UNESCO resolution, the UN General Assembly took up the matter for formally declaring 2005 as International Year of Physics. It may be noted that the UNESCO resolution in its 7th item of the text had changed the title of the

event from the World Year of Physics to International Year of Physics. Implicitly the idea was that if the UN General Assembly would agree to pass the resolution with the new title, the status of the event would have been upgraded. Indeed the General Assembly, in June 2004, adopted the resolution as contained in document A/58/L.62 and declared the year 2005 entitled as the "International Year of Physics" in place of the World Year of Physics. The General Assembly also invited the UNESCO to organize activities celebrating the Year, collaborating with physics societies and groups throughout the world, including those in the developing countries. The aims of celebration were announced by the representative of the Kingdom of Lesotho while introducing the text of the resolution, as

i. the aim of the International Year went beyond the mere celebration of one of the greatest minds in physics in the 20th century. The Year would provide an opportunity for the largest possible audiences to acknowledge the progress and importance of this great field of science.
ii. the Year should also be an occasion to begin prospective debates on the great need for scientific research in the 21st century. The debates would also have to relate to social issues which accompanied the practice of science, in general, and of Physics in particular.
iii. The ethical responsibilities for physicists were enormous.
Iv. The Year would allow all practitioners, especially women, to more actively participate in Physics' advancement

The same sentiments were expressed in the final statement to the General Assembly, which was cosponsored by Brazil, France, the Kingdom of Lesotho, Portugal, the U.K., the Principality of Monaco, with the later addition of St. Kits end Nevis and Croatia. The adoption of the above stated resolution by the UNGA provided two sets of definite ideas regarding the event. First, it laid down the scope and purposes of the Year and, second, it elevated the status of the event to the International Year. It is also important to note that the UNGA did not introduce any amendments to the text proposed by the UNESCO, which clearly indicates the importance and reverence the world body attaches to the prospective progress of Physics in the 21st century. Another noteworthy aspect of UN enthusiasm in endorsing the celebrations of the International Year of Physics – 2005 was that it recognized the potential of Physics to have a significant impact on the everyday life of all human beings, particularly pertaining to the socio-economic uplift of the standards of living in the developing countries.

As contained in the adopted UN General Assembly resolution, the UNESCO launched the International Year of Physics-2005 in its Paris Headquarters in the middle of January 2005. The event was then celebrated widely throughout the year, all over the world. It may be realized that the International Year of Physics-2005, although launched by the UNESCO after declaration by the IUAPP, was not to be placed under the confines of one organizational agency, but was to be regarded as a worldwide endeavour. It, eventually, acquired the desired international character and was welcomed by a broad- based world scientific community as one of its main items on

the calendar of the year 2005. As reported (www.wyp2005.org/activities.html and updated Oct. 2005), events were to be found on this occasion in 37 small and big countries of Europe, Canada and USA in North America, 16 Latin American and South American nations, 9 African countries, 17 Asian countries, 4 Middle, Orient nations and also in Australia and New Zealand. The same source also lists around 22 worldwide projects, encompassing a whole range of the diversity of activities related to Physics in connection with the celebrations. Such an overwhelming response was expected by the organizers, in order to achieve the objectives of the International Year of Physics-2005. The IYP-2005, indeed brought significant benefits to physicists, scientific organizations, universities and research groups in most parts of the world. It helped in increasing the profiles of those organizations which participated in the celebrations, built relationships amongst the physicists, created new avenues of funding and support, improved the communication-skills of the scientific staff and, most importantly, provided inspiration to the next generation of scientists.

Contributions from Pakistan's Scientific Community

The scientific community of Pakistan, especially the physicists, attached profound importance to the "International Year of Physics – 2005" and participated in the world-event with full interest and enthusiasm. A particular reason for this interest was the realization by the physicists of Pakistan that the problems facing the declining stature of Physics, and their likely solutions, were more or less the same as experienced by the world scientific community at large. Public awareness of the importance of Physics, sensitizing the governments and policy-makers to the role which Physics can play in socio-economic development and attracting the younger generation to enrol more enthusiastically in Physics courses, are some of the common objectives of the world science- community as well as of the Pakistan's scientists. It is important to realize that the aforestated problems are prevalent in many advanced countries also, where the knowledge-management competencies, technical and financial resources are not lacking. It is, therefore, a unique opportunity for all the nations of the world, rich and poor, to obtain benefits of the experiences of each other and try to solve the challenging problems identified for the progress of Physics during the course of the celebrations held so widely all over the world during 2005.

In Pakistan, much interest was shown in this world event by individual scientists, learned scientific societies, universities, colleges and schools, S&T organizations, teachers, students and the media. Simplicity, soberness and quality were the main features of the activities. Large attendance in the events by a wide cross-section of society, notwithstanding the financial constraints prevailing in these organizations, shows the seriousness that the nation attaches to the development of physics in the country. In these activities, particular attention was paid to the focused approach on the objectives set out, right in the beginning of the celebrations, by the international organizing committee and by the sentiments expressed by the world community at the UN platform. Another interesting feature of the celebrations was that a sizeable proportion of young women studying physics participated in the celebration activities.

MAIN EVENTS

In order to plan and implement activities of the International Year of Physics in Pakistan in an effective and meaningful way, a systematic approach was adopted. Prof. Dr. Khalid Rashid of the Quaid-i-Azam University, Islamabad, acted as the Coordinator (www.djz.edu.my/sciencecamp/eng). Right at the start of the worldwide celebrations, the Executive Director of the Commission on Science and Technology for Sustainable Development in the South (COMSATS), Dr. Hameed A. Khan, participated in the launching conference for the IYP-2005 held in UNESCO Head Quarters, Paris, from 13-15 January 2005. About 12 main events, comprising seminars, symposia, Physics Olympiad, etc., were planned during the year (www.wyp 2005.org/globe/asia/pakistan.htmail, updated December 2005). Several prominent physicists and educationists volunteered their valuable help and inputs to make the event a resounding success. All along the progress of the programme, the precious guidance, advice and participation of Dr. Ishfaq Ahmad, Special Advisor to the Prime Minister of Pakistan and a renowned Physicist himself, remained available wherever possible, to the organizers of the celebrations. Among the many scientific organizations, academia, learned societies, etc., particular efforts were made by the Quaid-i-Azam University, Islamabad; Panjab University, Lahore; Government College University, Lahore; Commission on Science and Technology for Sustainable Development in the South (COMSATS), Islamabad; Ghulam Ishaq Khan Institute of Engineering Science and Technology, Topi; Agha Khan University, Karachi; National Engineering and Scientific Commission, Islamabad; Pakistan Atomic Energy Commission, Islamabad and Pakistan Science Foundation. COMSATS offered premises, secretariat and logistical services at its Head Quarters to manage many seminars, symposia and meetings related to the IYP-2005 activities throughout the year. It is noteworthy that several prominent physicists working in various renowned universities abroad also visited Pakistan and participated in the seminars, symposia and discussions arranged to celebrate the occasion.

A short summary of some of the related events is given in the following pages:

a. International Seminar on "Physics in Our Lives"

COMSATS organized this two-day international seminar (Feb. 23-24, 2005) at Islamabad, in collaboration with the Pakistan Atomic Energy Commission and the National Centre for Physics, Quaid-i-Azam University, Islamabad. The purpose of the seminar was to highlight the ongoing efforts of physicists and their future plans for improving the quality of life of the people by application of the science of physics. It also aimed at (i) providing a forum for interchange of ideas between academia, researchers and the industrial sector, with reference to the role of physics in improvement of the society, (ii) facilitating the public awareness of physics, its economic necessity, its cultural contributions and its educational importance, (iii) providing a medium through which participants could get to know their improved career prospects, (iv) strengthening the linkages between researchers of different

institutions and industries and fostering future multi-institutional collaboration in the field of basic and applied physics and, finally, (v) generating sound recommendations for addressing problems concerning the role of physics in society through assessment of research-capacity and identification of high-impact areas leading to refocusing of efforts and of new funding.

The seminar was attended by 29 speakers, including 4 foreign experts representing the countries of Switzerland, Syria, Egypt and Sudan. Other participants included eminent physicists, heads of S&T organizations, scholars and students from various academic and research institutions. COMSATS compiled and published 21 presentations of the seminar in the form of a book, entitled "Physics in Our Lives" in July 2005. The book was distributed among the participants, universities, industry, developmental organizations and R&D institutions as a part of COMSATS policy of prompt dissemination of new knowledge, as widely as possible.

b. 30th International Nathiagali Summer College on Physics and Contemporary Needs – Special Session on the IYP-2005

This prestigious internationally renowned Summer College dedicated a full session to the celebrations related to International Year of Physics on 27th June 2005. The International Summer College is annually organized by the Pakistan Atomic Energy Commission, to keep abreast of the latest developments in various branches of Physics and its applications to the contemporary needs. The special session on IYP-2005 was chaired by Dr. Ishfaq Ahmad, Special Advisor to the Prime Minister of Pakistan, who also gave the introductory and concluding remarks.

During the special session, the first lecture was given by Prof. Sreenivasan, Director of Abdus Salam International Centre for Physics (AS-ICTP), Trieste, Italy. Besides paying rich tributes to the Pakistan Nobel Laureate in Physics, Prof. Sreenivasan presented physics-related activities of ICTP, that were of benefit to the scientists of the developing countries. He also pointed out the need of producing good physicists from the developing world who could effectively take part in the ICTP activities.

The next lecture was delivered by Prof. Dr. Ahmad Ali of DESY, Germany which was focused on Einstein's works in the realm of Physics. He also talked about the life of this great scientist.

Prof. Dr. Riazuddin, Director General, National Centre for Physics, Quaid-i-Azam University, Islamabad spoke on the detailed achievements of Physics in the 20th century and the likely future course of its developments in the 21st century. The title of Prof. Riazuddin's talk was "The Century of Creativity".

The last lecture of the session was from Prof. Zubairy from the University of Texas A&M, USA. His lecture was entitled "From Einstein to Bell". He talked, inter alia, about Quantum Mechanics, the EPR paradox and the current status of our

understanding related to the foundation of Quantum Mechanics.

The importance of the International Summer College on the subject of Physics can be envisaged by the fact that high level government dignitaries usually participate either in its opening or closing ceremonies. The year too, more so due to the IYP-2005 celebrations, the inaugural session was chaired by the President of Pakistan. He particularly referred to the importance of science and technology for the development of any country. He also pointed out that development of science and technology was necessary to bring economic prosperity in a nation, and alleviates poverty, which is generally the root cause of any social and other problems.

The special session of the Nathiagali Summer College, devoted to the International Year of Physics-2005, proved very useful and effective in achieving the objectives foreseen by the coordinators of the celebrations in Pakistan. The wide range of interest of the audience, comprising high government officials, policy makers, researchers, R&D organizations, industry, educationists and commercial enterprisers, participants in the deliberations on this particular occasion, provided an excellent opportunity to revive the importance of physics in achieving socio-economic betterment in Pakistan,.

c. Conference on Nano-Science and Technology in Pakistan

The Conference on nano-science and technology in Pakistan was organized by COMSATS, in collaboration with the National Commission on Nano-Science and Technology of Pakistan (NCNST) from 13-14 June 2005. Owing to the revolutionary potential of this rapidly emerging science and related technology in the world and its special significance to Pakistan in its socio-economic development, it needed an appropriate occasion to highlight its importance to the researchers, industry, businessmen and policy makers. The IYP-2005 provided this opportunity in a logical and befitting manner. One of the key objectives of the Conference was to find out ways and means to create an extensive data- base of the scientists and institutions involved in the field of nano-science and technology, so that national policy can be focused to strengthen the knowledge available in this promising field and to develop programmes of basic and applied research. The idea was also to attract a maximum number of young physicists to take reading courses in nano-science and technology and develop interest in making a career out of this new field.

With the above background and objectives in mind and with the realization of the widely diverse applications of nano-science and technology, the speakers were invited from academia, industry, business and S&T organizations to deliberate on the relevant issues, such as:

i. Nano-science and technology and their applications;
ii. Identification of areas, interventions and policies by the government to accelerate the development of nano-science and technology;
iii. National projects and initiatives in the field of nano-science and technology by

various national organizations;

iv. Future business, its commercial scope and impact on the economy of Pakistan;
v. Role of various beneficiaries of nano-science and technology, such as manufacturing industry, scientific organizations, as well as academic and research organizations for the promotion of nano-technology;
vi. Means and modes for public-private partnerships and fund-Generation;
vii. Areas of international cooperation and synergies, as well as governments' role as facilitator, etc.

In addition to the objectives of preparing data base, the Conference was designed to trigger debate on the various other aspects of the subject and to prompt some useful suggestions, recommendations and policy guidelines from the participants.

The subject of the Conference attracted enormous interest and response. About 34 papers on a variety of related topics were presented by scientists, engineers, metallurgists, medical professionals, researchers of R&D laboratories, etc. The audience overwhelmingly participated in the lectures, discussions and question & answer sessions. Several useful guidelines and suggestions emerged, as a result of these activities, and provided the basis for the vision, teaching, research direction and mode of interaction of researchers with industry, academia and to the National Commission on Nano-Science and Technology. The Conference also produced useful ideas for the guidance of policy-makers, both in government and private sectors.

This important event, related to new science and industry and also having close links with the basic and applied physics, was again an appropriate effort by Pakistan's scientific community to make good use of the opportunity provided by the IYP-2005. It is highly desirable that the existing base of nano-science and technology in Pakistan be expanded considerably, in order to make Pakistan an efficient competitor of the advanced countries of the world.

d. International Seminar on Physics in Developing Countries: Past, Present and Future

This international event was organized jointly by COMSATS and the Islamic Educational Scientific and Cultural Organization (ISESCO) in Islamabad from 27-28 July, 2005. The objectives of this seminar were linked to those of the celebrations of the IYP-2005. A particular aspect was the relevance of physics to the sustainable economic development in the developing countries. The main issues to be addressed during the seminar were:

i. The evolution of physics as the basis of all sciences, stressing the key development stages throughout history, as well as the present scenario.
ii. The methodology for enhancing awareness of the potentials of physics for improving the lives of the people, particularly those of the developing world.
iii. The need for greater interaction between physics and other sciences in the solution

of environmental and industrial problems, in view of the interdisciplinary nature of economic growth.

iv. The development of necessary infrastructure and institutions to support physics, as well as the means of carrying out satisfactory experimental physics in relatively simpler laboratories, through suitably thought-out programmes.
v. The importance of international cooperation in physics and requisite modalities of instituting and promoting South-South and South-North cooperation
vi. The framework for slopping the brain drain of scientific talent, and assessing the suitability of sandwich fellowships.
vii. Ways to enhance capacities of the current cadre of physicists in developing countries.
viii. Methodology to promote and support initiatives that show how physics can help the economy.

Participants from foreign and Pakistani universities, S&T institutions, etc., delivered informative lectures, which were highly appreciated by the audience comprising academia, industry, researchers, media, students at graduate and postgraduate levels and technical people working in various R&D organizations. It was realized that awareness of physics, planning, implementation and ethics are key-components for drawing effective benefits from the potentials offered by physics. Underdeveloped societies are not, so far, well equipped with the necessary management tools to acquire the true benefits from the potentials of physics.

Some of the most important and interesting lectures (18 papers) covered a wide spectrum of issues facing the developing countries where the strengthening of physics can play a useful role, a point which was high on the agenda of the IYP-2005 celebrations. Speakers from Sri Lanka, Saudi Arabia, Egypt, Sudan, Tajikistan and Pakistan covered topics, such as the experience of physics in the societies, physics-based industrial linkages, environmental and economic applications, renewable-energy technologies, laser applications, sustainable development, education in physics, low-energy particle-accelerators, space physics, etc. One of the most interesting presentations which was directly aimed at encouraging young students to take up physics as their career, was given by the Rector of GIKI, Topi. The efforts by Pakistani physicists to promote this objective under the STEM Project (Science, Technology, Engineering and Mathematics) with the assistance of Higher Education Commission of Pakistan and utilizing Physics Olympiad mechanism, received particular attention and appreciation of the audience. COMSATS is disseminating the knowledge emerging out of this successful seminar, through the publication and its distribution based on the seminar's proceedings.

e. Conference on Role of Physics in Biology and Medicine

An important Conference in connection with the IYP-2005 was organized by Agha Khan University, Karachi in September 2005. The main objective of the Conference was to highlight the important applications of physics in medicals sciences and how

this crucial inter-relationship has helped the humanity in the diagnosis and treatment of various ailments.

In his keynote address conveyed to the Conference, Dr. Ishfaq Ahmad, Special Advisor to the Prime Minister of Pakistan and a noted physicist, intimated that physical sciences form the bedrock on which other scientific disciplines are built. This relationship has recently been well recognized in the establishment of the field of biophysics. He said that there was a long and rich history of applying physical principles and the development of many types of technology for both diagnosis of disease and injury and for a variety of therapeutic purposes. He also mentioned the importance of scientific work done by Einstein a century ago in the realm of physics which has helped the mankind in understanding the hitherto several unexplained natural phenomenon.

Some interesting and important links between physics and techniques applied in medicine were indicated by the President of Agha Khan University, Mr. S.K. Lakha in his inaugural address. He said that the Conference brings together fellow academics as well as anyone interested in science and its role in the society to celebrate the IYP-2005. He was of the view that if, as a result of the Conference, some of the related quarters develop an interest in the role of physics in biology and health sciences, and try to develop ideas about interdisciplinary approaches, it would then be a success of the Conference.

According to the Conference programme in the pre-Conference workshops, around 12 specialists and experts read papers on a range of topics covering applications of physics in medical sciences, radiology and nuclear medicine, anesthesiology, cardiology, lasers, MRI, ultrasound, x-rays techniques etc.

The knowledge value addition to the Conference proceedings was ensured by the panel discussions and question-answer sessions. The Conference, thus, proved to be a befitting tribute to Einstein and served as an excellent occasion to provide scientific and intellectual inputs to the celebrations of the IYP-2005.

f. Popular Lecture on "Einstein - the Genius of the Century"

A specific gathering of scientists, researchers, university and college teachers, physicists from various R&D institutions and school and college students was arranged by the Pakistan Science Foundation in Islamabad on the World Year of Physics-2005 on 29th December 2005. The lecture was delivered by Prof. Dr. Khalid Rashid of the Quaid-e-Azam University, Islamabad, who is also a Member of the International Steering Committee set up for the World-Year of Physics-2005. Pakistan Science Foundation hosted this event in its premises. The Chairman, Pakistan Science Foundation, Dr. N.M. Butt informed the audience that this lecture was specifically designed to address the young students from schools and colleges. He also said that several activities related to the IYP-2005 were being arranged by the Quaid-i-

Azam University and the Government College University, Lahore.

A very encouraging and innovative aspect of the lecture was that, in addition to the main speaker, boys and girls from various local schools and colleges gave short speeches on the life and achievements of Einstein. These speeches were of high quality and contained some very interesting material regarding Einstein and the IYP-2005 celebrations. It was evident from the participation of younger generation of physics-loving students and from the question-answer session that a great potential does indeed exist in the student community to take serious interest in physics and to make this science as their career, both in teaching and in research. In this respect, the efforts of Pakistan Science Foundation and the organizers of the lecture certainly achieved the objective of arousing popular interest in physics and converge the students' potentialities towards adopting physics as their career.

Another outstanding achievement of the event was that the free exchange of ideas and experience among the participants during the question-answer session pointed to the recommendation that it was necessary to enhance the capacity of the scientific institutions in the country. As a part of the celebrations of the IYP-2005, the Pakistan Science Foundation prepared a small brochure containing the brief life- history of Einstein, his most important scientific works, awards and degrees, his quotes and some indication of his non-scientific work. This idea was well received by the scientists and appreciated as a quick source of information on Einstein and the twentieth century physics.

BENEFITS AND IMPACT ON THE SCIENTIFIC COMMUNITY OF PAKISTAN

The idea of celebrating the International Year of Physics – 2005 was widely welcomed by the scientists of Pakistan, in general, and the physics community in particular. The large number of activities undertaken in Pakistan, to make the objectives of the IYP-2005 a success, clearly speak of the interest and importance attached to this event by the physicists of Pakistan. The large participation by a wide spectrum of the scientists, educationists, students, industrial entrepreneurs, researchers, learned societies, media, etc., has generated awareness and revived interest in physics and its potentials to make mankinds' life more comfortable and humane.

As indicated in earlier sections of this text, the idea of IYP-2005 was that it should not remain confined to mere celebrations, but should go much beyond that. It should enable the people to take a good look at the status of physics as it exists today, and take practical steps to improve its health in order to render it much more serviceable to humanity than it is capable of doing it in the present age. It should also sensitize policy- makers and government functionaries to understand the contributions that physics can make to the socio-economic uplift of the society and to involve more physicists in the processes of policy and decision-making. Many other related aspects were recognized by the organizers of the event, as have been mentioned in the earlier part of this write-up.

The main benefits and impact that the celebration of IYP-2005 have brought to the scientific community of Pakistan are briefly mentioned below:

i. It has provided an opportunity to acquire renewed awareness of the current status of physics in Pakistan and to set out a better understanding of the future trend of its progress, in relation to its international evolution.
ii. It has been realized that physics is not entirely a disabled science in Pakistan, but has the potential to evolve to world- standards if appropriate vision is in place and implementable policy-decisions are taken at the higher level.
iii. A close watch by Pakistan's scientific community at the world events that have taken place in connection with the IYP-2005, has helped in enriching scientists' knowledge of the latest trends in physics and its spin-offs so as to make physics a beneficial science for the interests of Pakistan.
iv. The teaching of physics and mathematics at secondary, higher secondary and undergraduate levels in Pakistan needs prudent changes. Activity-based teaching that engages students in the learning process and not the old "chalk and talk" methods are to be employed if the quality of physics has to be raised in Pakistan.
v. The scarcity of able physicists and mathematicians is not only the problem of the underdeveloped countries, but is now increasingly being seen in the advanced countries also. It would be beneficial for the world scientific community, as a whole, to engage in joint collaborative efforts of improving teaching, experimenting and researching, so that an international high standard of learning and practicing physics is achieved. International hubs of centres of excellence, with liberal intake policies from the developing countries, would be desirable to create a critical mass of physicists and mathematicians both at national as well as the world level.
vi. Government and private organizations responsible for teaching and research in physics are currently not providing adequate incentives to the students to take up physics careers. Basic physics and research is under tremendous stress, as a large majority of good physicists abandon basic research and move on to work for industrial enterprises. This is causing continuous brain-drain at the intra and inter-country levels. Reversing such trends would create useful impacts on the welfare of the scientific community, as well as on society as a whole.
vii. In the developing countries, there is an acute shortage of women-physicists, both in teaching and in research. More enrolment of female students in the educational institutions, with career incentives, is needed at the policy level. Gender disparity in physics leads to negative impact on the science-based economy of any society.
viii. The physics curricula should include topics such as ethics of practicing science and code of conduct for the scientists and researches. Appropriate attention should also be given to the practice of safety-standards while undertaking the laboratory work by the scientists and researchers. The good safety culture in laboratories of the universities leads to safety against industrial accidents and limits the production of hazardous industrial wastes. Such practices will create a positive impact on the environment, which is becoming an increasing concern of the modern industrial age.

ix. A major impact of the celebrations of IYP-2005 on Pakistan's physics community has been that more scientific contacts have been established amongst the physicists within the country and abroad. As a result, more avenues of communications have opened up for the exchange of ideas and experience on innovative techniques, which have surfaced as a consequence of IYP-2005 events throughout the world.

x. One of the outstanding benefits of the IYP-2005 has been that the world has been enlightened afresh about the role that physics can play in the sustainable socio-economic development of the emerging economies. Pakistan can fine tune its scientific approach to address its priority economic needs by appropriately focusing upon the potentials of physics, in the light of new experiences, information and strategies available as a result of the scientific activities carried out in connection with the IYP-2005.

CONCLUSIONS

The worldwide celebrations of the IYP-2005 have provided enough inputs to the physics community to take up the follow-up actions needed to fulfil the objectives of the IYP-2005. A relevant and befitting event concerning this aspect was the World Conference on Physics and Sustainable Development held in Durban, South Africa from 31 October – 2 November, 2005. It was jointly organized by UNESCO, the Abdus Salam International Centre for Theoretical Physics (ICTP), the International Union of Pure and Applied Physics (IUPAP) and the South African Institute of Physics (SAIP). Around 350 people from around the world participated in this Conference, including representatives of physics organizations and the private sector.

The Conference was a unique opportunity for the international physics community to join efforts and come up with a plan for tackling some of the large problems facing the world. The contributions made by physics in the past to the welfare of society are numerous. These contributions are ongoing, but the larger benefits are going to the developed rather than the developing nations. This Conference gave the physicists of the world a chance to begin to focus on how they could collectively work to bring more benefits of physics to the less developed world.

The most important feature of the Conference having direct relevance to the goals and objectives of the IYP-2005 was the emergence of a Resolution which provided a basis for commitment of the world physics community on specific issues identified during the Conference deliberations and an action plan proposed in the form of well defined projects to achieve the goals agreed in the Conference. The main themes which could have a direct impact on the society at large and which also structured the main body of the Conference resolution and drew the attention of the participants were (a) Physics Education (b) Physics and Economic Development (c) Energy and Environment and (d) Physics and Health.

The Conference not only addressed the issues formulating the major objectives of the

IYP-2005 but also renewed interest in the work done in earlier conferences (UNESCO-ICSU World Conference on Science, June 1999 and the UN World Summit on Sustainable Development, Johannesburg 2002). It also identified areas where physics can play an important role in socio-economic development in the world. It is expected that the action plan of the Conference will be collectively implemented by the various organizations of physicists, including national physical societies, etc.

The outcomes of the IYP-2005 and the World Conference on Physics and Sustainable Development provide ample substance to the physicists of Pakistan to strengthen the foundations of physics in the country, to take proactive approach to establish scientific collaboration with the world's renowned physicists and the physics laboratories and to strengthen ties between physics and the society. The IYP-2005 has shown that the enviable progress made in the field of physics in the advanced nation during the last century was only possible due to sustained support of the governments and the industry. Pakistan cannot be an exception to this universal rule. The IYP-2005 seeks to send this thought provoking signal to the Pakistan's society at this right moment which needs to be acknowledged with seriousness and care.

The formal closing event of IYP-2005 was held in the European Centre of Nuclear Research (CERN) on 1st December 2005. The function was in the form of a continuous webcast from 12.00 to 24.00 hrs. The title of the event was "Beyond Einstein". Further information or details of the programme are available on the website public.web.cern.ch

RECOMMENDATIONS

Lessons learnt as a result of the IYP-2005 celebrations lead to some recommendations, which may prove useful for the progress of physics in Pakistan. A few are given below:

i. The various IYP-2005 related scientific events held in the world have generated useful knowledge and experience. Information relevant to Pakistan may be extracted from the body of this knowledge and experience by a panel of eminent physicists of Pakistan and appropriately utilized in the teaching of physics and in basic research. This activity could be undertaken with the participation of Pakistan Science Foundation and Pakistan Physical Society, either jointly or separately.
ii. Coordinated Research Projects (CRP's) may be established between the physics organizations of Pakistan and the relevant world renowned counterparts on the themes identified in the World Conference on Physics and Sustainable Development held in Durban, South Africa (31 Oct. – 2 Nov. 2005). The HEC of Pakistan can play an important role in this regard.
iii. Physics organizations and the Government of Pakistan may be urged to launch campaigns to popularize physics among the masses. Print and electronic media, mobile exhibitions, specific scholarships at school, college and university level to read physics and mathematics, physics essay competitions at grass root level and

establishing a world-class physics museum in Pakistan will help create awareness and interest in physics at general public level.

iv. Nobel Laureates in Physics may be invited to Pakistan as State Guests for short periods of time (one week) to deliver popular lectures to secondary school, college and university students all over Pakistan. Wider networking of such lectures could be organized through tele-conferences and through popular TV channels. Radio talks in the local languages originating from these lectures could also be broadcast all over the country, through well designed programmes.

v. There is a strong need to raise the quality of physics teaching and research in the country. The IYP-2005 has come up with new and innovative ideas to achieve quality education and research. Experiences of Physics Education Research (PER) groups of the USA and of UNESCO, through the efforts of the Asian Physics Education Network (ASPEN) for active learning methods, rather than the passive learning methods in physics may be given due attention. Relevant projects in Pakistan at test-level could be fruitful.

vi. A Standing Advisory Committee of renowned physicists, educationists and researchers may be established on all Pakistan basis to keep a continuous watch on the status of physics in the country and publish reports, at regular intervals, on the assessment and evaluation of the progress being achieved to improve the quality of physics teaching and basic research, both in the private and public sector organizations. The proposed Advisory Committee should have an independent status and may send its findings and recommendations to the Government of Pakistan through Pakistan Science Foundation and through Pakistan Academy of Sciences.

vii. A special fund may be created to undertake projects on new techniques of teaching-physics and to create bastions of original, creative and imaginative basic research in selected universities and other research organizations. These projects should not be assessed on the number of publications, but merely on the quality of knowledge created by the researchers. Emphasis should be on knowledge-creation and not on information-generation. This aspect could be one of many others, to change the culture of physics research in the country.

By no means should one assume that the above-stated recommendations are the only ones to improve the status of physics in Pakistan. Several other ideas may prove to be more useful and appropriate. These ideas will have a possibility to be tried and tested by various competent fora of physics in Pakistan and may also have positive complementary impacts to achieve the much desired purpose of taking physics to a much higher status than it enjoys today in the country. The IYP-2005 has, indeed, provided the opportunity to all of us to come up with such new ideas and to devise ways and means to implement them for the assured results. No doubt, the physics community of Pakistan has the resolve and competence to follow up the outcomes of the IYP-2005 and to transmit its benefits to the society in Pakistan's best national interests.

REFERENCES FOR FURTHER READING

1. www.wyp.2005.org
2. www.djz.edu.my/sciencecamp/eng
3. www.physics.2005.org
4. www.comsats.org.pk
5. www.psf.gov.pk
6. www.un.org
7. www.saasta.ac.za
8. www.cap.ca
9. www.ncp.edu.pk/insc
10. www.wcpsd.org
11. Erdelen.W.,Editor, A World of Science, Vol 3, No.1 (2005) p.1
12. Alarcon.M.,ibid, Physics without Tears, pp.2-7
13. Schopper.H.,ibid,Einstein's Legacy, pp.14-16
14. Relevant Articles, IAEA Bulletin, Vol.47, No. 1, (Sept.2005)

50+5 YEARS OF PHYSICS IN PAKISTAN, A PERSONAL PERSPECTIVE

Riazuddin
National Centre for Physics, Quaid-i-Azam University Campus,
Islamabad, Pakistan.

ABSTRACT

Fifty five years of Physics in Pakistan have been analyzed from a personal perspective. Successes and failures, together with their causes, are also discussed. The current trends in development of Physics are also mentioned.

EARLY PERIOD 1947-1959

Before independence, the institute of Chemistry at the Punjab University was well established under the leadership of Dr. Shanti Saroop Bhatnaggar. At the time of partition of India, many good chemists remained in the newly formed Pakistan, but Physics was left almost at zero when most of the top physicists left for India. At the Punjab University, only Dr. Abdul Majid Mian was left. Later, in the early 50's Drs. R. M. Chaudhri and M. Ishaq migrated to Lahore from India. Dr. R. M. Chaudhary joined the Government College Lahore and, dedicatedly, established experimental physics facility there. A little later, Dr. Mujtaba Karim established a Physics Department at Karachi University, A. B. Pal joined Punjab University, and in 1956 Dr. M. Aslam Khan established an Atomic Spectroscopy Laboratory at Karachi University.

Dr. M. M. Qurashi (who attained his Ph.D in 1949 from the Govt. College Lahore) joined PCSIR, while Dr. M. Sultan and M. Afaf after joining Government College, Lahore left, for jobs, elsewhere Dr. Tahir Hussain who joined GC, was mainly engaged in teaching.

Except for Dr. Mian, all the others were experimentalists. Prof. Abdus Salam came back for a short period (1951-53) and joined Government College Lahore as Professor of Mathematics and simultaneously became chairman of Math department at the Punjab University. The first slide represents the flavour of publications for the early period (1950-1959) as appeared in the Physical Review (nothing seems to appear before that, at least in the Physical Review).

All the data I am going to present is from the American Physical Society (APS) journals (mostly Physics Review and Physical Review Letter) for the following reasons.

- This is the only source available to me.
- APS journals have one of the highest refereeing standards.

- They have high Impact Factor as they are widely read.

One may say that this is biased, may be so. But the conclusions which I will draw at the end, will be quite general. I divide the 50 + 5 years by decades, except the first decade 1960-1969 which I subdivided into two: 1960-1966 and 1967-1969 for the reason that the Physics researched shifted from Lahore to Islamabad after 1966.

1960-1966

Some positive developments took place: Dr. I. H. Usmani became chairman of Pakistan Atomic Energy Commission (PAEC) and together with Prof. A. Salam as a part time member of PAEC (later he became Chief Scientific Advisor to the President of Pakistan), revitalized the commission with the following results:

Results of Physical Review Search

[Back to Search form]

Expand/Refine Search:

AND | Abstract/Title: | MATCHES |

Refine Search

Showing results 1 through 5 (of 5 total) for pakistan

1. **Energy Levels in Fluorine-19 Nucleus**
   A. Hossain and A. N. Kamal
   Phys. Rev. **108**, 390-392 (1957) [View Page Images or PDF (420 kB) [Order Document]]

2. **Emission of Electromagnetic Radiation by the Impact of Positive Ions of Hydrogen on Metal Surfaces**
   R. M. Chaudhri, M. Y. Khan, and A. L. Taseer
   Phys. Rev. **104**, 1492-1493 (1956) [View Page Images or PDF (444 kB) [Order Document]]

3. **Nuclear Energy Levels of Be^8 from $Li^7(d, n)Be^8$**
   M. A. Ihsan
   Phys. Rev. **98**, 689-690 (1955) [View Page Images or PDF (353 kB) [Order Document]]

4. **Renormalization**
   P. T. Matthews and A. Salam
   Phys. Rev. **94**, 185-191 (1954) [View Page Images or PDF (1198 kB) [Order Document]]

5. **Fredholm Theory of Scattering in a Given Time-Dependent Field**
   A. Salam and P. T. Matthews
   Phys. Rev. **90**, 690-695 (1953) [View Page Images or PDF (949 kB) [Order Document]]

- A massive training program was started by PAEC
- The status of Scientists was raised.
- Atomic Energy Centre was established by PAEC at Lahore.

- This was joined by many Physicists who returned after their Ph. D. Anwar Hussain, Abdul Ghani, Ishfaq Ahmed, M. A. Shaukat established the emulsion group in Particle Physics, but this was not sustained.
- Naeem Ahmed Khan and Sabtain Bokhari were interested in low-energy nuclear physics and Saeed Durrani joined for short period, but then left PAEC.
- Theoretical Physicists working at Lahore Centre were:
  Riazuddin, F. B. Malik, Raza Tahir kheli and Fayyazuddin.
- Professor M. J. Moravscik visited the Lahore centre during 1962-1963 under International Atomic Energy Agency (IAEA) and describing his stay was a morale booster for the group.

1967-1969

The scene shifted from Lahore to Islamabad. The institute of Physics was established at the University of Islamabad. The pioneers were Riazuddin, Fayyazuddin, Faheem Hussain, A. Q. Sarkar, Haroon-ur-Rashid, M. A. Rashid, Arif-uz-Zaman, Saifuddin, Gulam Murtaza, S.K. Razmi, Kamaluddin Ahmed. They formed the Theoretical Physics group. Others physicists were Masud Hussan, and M. Ijaz. The latter established teaching Laboratories and introduced the Fortran Programming for the first time in the University. For the first time in the history of Pakistan, a regular postgraduate program in Physics was started. Later, the Institute of Physics diversified to Condensed Matter Physics, with A. H. Nayyer, M. Zafar Iqbal and Hamdani as pioneers. Below I give the Publication Analysis.

Perhaps a better indicator of research is number of publication per author or ever better per scientist. These are given below;

The following comments on the above graph are in order:

- Peak is in the period 1967-1969, followed by a slightly lower peak in the decade 1970-1979.
- Sharp fall after 1979: Some pioneers left, very few new young persons joined.
- Slight rise between 1980-1989 and 1990-1999 as Pervez Hoodbhoy and Suhail Zubairy joined. Again, one sees a slight decline as Pervez Hoodbhoy's interests became wider and Zubairy left.

REASONS FOR SUCCESS

1. Patronage at Highest Level

President M. Ayub Khan became personally interested in the development of the University of Islamabad;

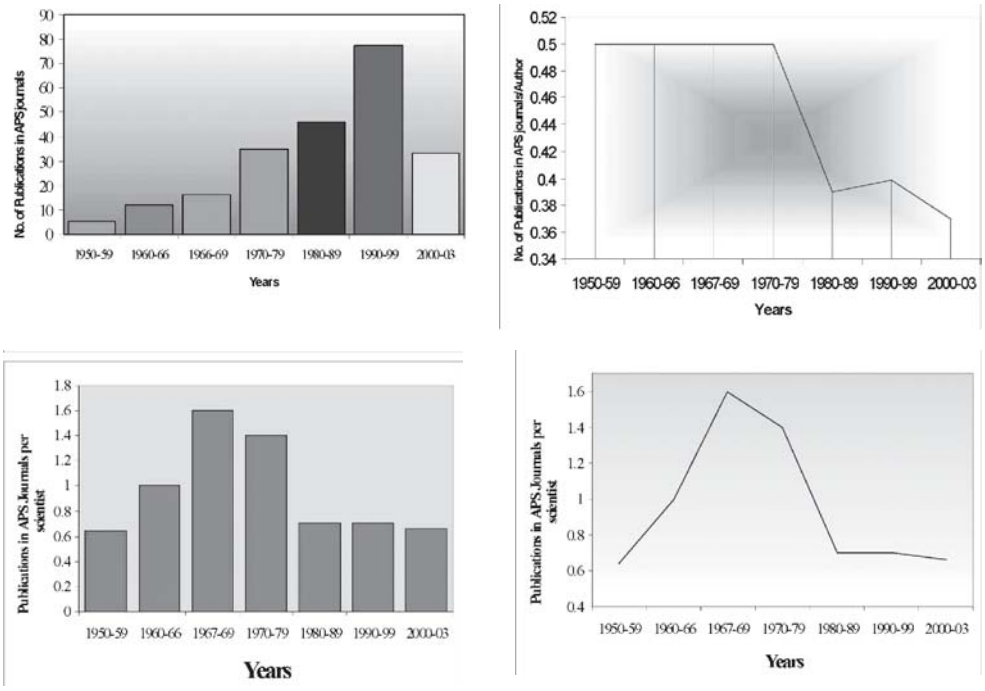

Figure - 1: Number of Publications

2. Appointment of a Competent Vice-Chancellor

Dr. M. Raziuddin Siddiqui, an eminent educationist who himself went through the process of Higher Education, educated at Cambridge and Leipzig where he rubbed shoulders with the topmost physicists and mathematicians of that era, was appointed the first Vice-Chancellor.

3. A New Concept of Structuring the University

This was done in the form of institutes, rather than departments. Each institute was headed by a Director who was also the Dean of the faculty, enjoying considerable autonomy, particularly in the academic appointments;

4. Critical Size

Young faculty were attracted by offering them positions at a level higher than what they would normally get in any other university and assuring them that they would not be isolated. Thus, young people in their late twenties or early thirties were appointed at associate-professor level. Efforts were also made to collect a critical number of trained scientists at place. Once a critical number is reached, a chain-reaction starts and the group becomes self-sustaining. Otherwise, it is simply withers and dies away.

5. Mobility and International Contacts

To ensure greater mobility of faculty and to provide them with international contacts, the following steps were taken:

I. Liberal sabbatical leave rules, which would enable the members of a faculty to get a sabbatical leave after every three years of service.

II. International support and its effective utilization in the following forms:

a) The Ford Foundation grant (which the V. C. could somehow succeed to obtain) used for short-term international contacts. This enabled us to invite distinguished visitors from abroad for visits, lasting one to three months, where research was going on in the fields at the Institute. Also, under this grant, funds were available for the members of the Institute to attend International Conferences.

b) The support of the International Centre for Theoretical Physics at Trieste, Italy, for visits of the faculty to that centre during the summer vacation. The UNDP grant, which was mainly used for the development of experimental facilities and for long term visitors relevant to the fields to be developed.

6. Idealism of the Youth

It was the idealism of the youth that not only enabled many of us, (who could have stayed abroad), to return, but also infused a great enthusiasm to succeed in the pioneering role of establishing a new institution from scratch;

7. Quality assurance

To maintain quality, the concept of contractual service was introduced for the first time in Pakistan, in the sense that the work of a faculty member would be evaluated after 3 years before giving him tenure. The results were spectacular; within 4 years, the Institute of Physics was on the international map. For the first time in the history of Pakistan, a postgraduate-program leading to Ph.D. degree in Physics was started on a regular basis. The Ph. D's produced were of international standard.

SUBSEQUENT TRENDS

Development of science and technology requires more than material infrastructure. It is the development of manpower at different levels that fosters it. In Pakistan, adequate attention has not been given to this aspect of development of science. Professor Moravcsik who visited Pakistan several times, wrote in his letter to the president of Pakistan, after his last visit in 1987:

> *"In surveying Pakistani scientific manpower, one is struck by its being overwhelmed by older people. In 1962, when I first come in contact with Pakistani science, there was a large group of bright young men in the sciences, many still in the progress of being educated at an advanced level, but most already showing talent and achievement. Many of them*

contributed to science significantly in the following years. Members of that generation today are in their mid-forties or mid-fifties, some still productive, but the group, on the whole, is declining in its contribution to research, perhaps because of administrative preoccupations, or perhaps just out of general tiredness."

This is well illustrated in the next two slides.

(The above chart indicates the Physics as measured by Journal Cumulative Impact Factor)

STATUS AND FUTURE TRENDS

Below I give a summary and trends in question and answer form Questions were asked by Edwin Cartlidge, News Editor, Physics World in the Connection with an article on November 30, 1999 he was writing for "Millennium" (Dec.) issue of Physics World on Physics in the developing world:

Q.1: The major areas of research in Pakistan?
They are Condensed Matter Physics (Semi-Conductors, High Temperature Super-Conductivity, Magnetic Materials and Simulation); Lasers and Atomic Spectroscopy; Quantum Optics; Plasma Physics; Nuclear and Reactor Physics; High Energy Physics (Mainly Theoretical).

Q.2: Major Research Facility that presently exist [A list of Largest facilities such as neutron or synchrotron sources]
10 MW swimming pool Reactor at PINSTECH: Used mainly for neutron diffraction studies, reactor physics, radiography, isotope production and neutron activation analysis. In addition as is international norms, the National Centre for Physics pursues a small number of activities in the experimental high energy physics through a cooperation agreement (already signed) with CERN in Geneva. This work is centered around CERN's CMS (Compact Muon Solenoid) detector at Large Hadron Collider (LHC).

Q.3: Has there recently been any physics research carried out in Pakistan/by Pakistanis that have made major breakthroughs?
Really major breakthroughs are rare even in developed world. I can mention two highly cited works: One is known as Kawarahayashi-Suzuki-Riazuddin-Fayyazuddin (KSRF) relation in the literature on particle physics. Kawarahayshi and M. Suzuki, Phys. Rev. Letters 16, 255 (1966) and independently by Riazuddin and Fayyazuddin, Phys. Rev 147, 1071 (1966): (No. of Citations 579). The other paper is on squeezed states in Quantum Optics by P. Meeystre and M. S. Zubairy, Phys. Letters 89A, 390 (1982). This paper has 210 Citations.

One may also mention influential books co-authored or authored by Pakistanis i):

Theory of Weak Interactions in Particle Physics, R.E. Marshak, Riazuddin and C. P. Ryan, Wiley-Inter science (1969), which is regarded as a classic and has more than 582 Citations. ii): A Modern Introduction to Particle Physics, Fayyazuddin and Riazuddin. World Scientific, (1983) (2nd Edition October 2000). This is adopted as a text book in prestigious universities, like Universities of California, Santa Barbara and Irvine. Got very good reviews in Physics Today, Jan. 1994, and in Contemporary Physics, 2002, Vol. 43, 12. iii): Quantum Optics, M. O. Scully and M. S. Zubairy, Cambridge University Press (1997). Got very good review in American Journal of Physics 67, 7th July, 1999 and Physics Today, Oct. 1998.

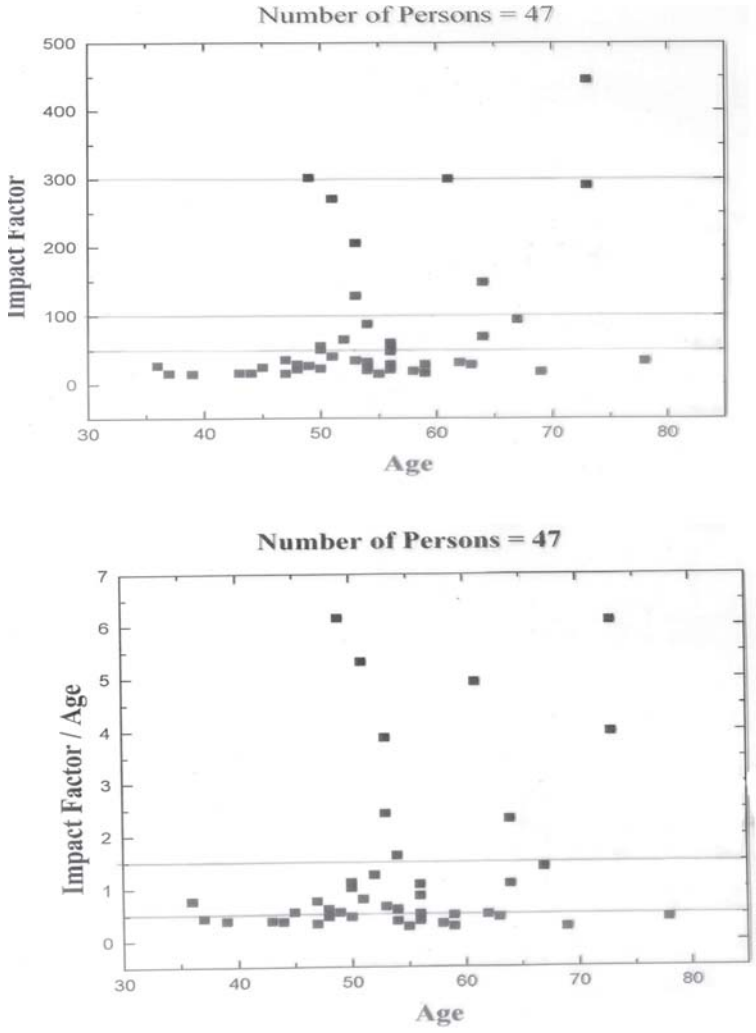

Figure - 3: Moreoverthe physics is concentrated in fewcentersas the next fewslides illustrate (Source PCST book 2000)

Institutions	Scientists	Cumulative Impact Factor
Pakistan Atomic Energy Commission	19	971.996
National Centre for Physics	02	736.693
Quaid-i-Azam University ?Department of Physics ?Department of Electronics	14 04	715.479 297.308
Commission on Science and Technology in South	01	300.244
University of the Punjab ?Centre of Excellence in Solid State Physics ?Centre of Excellence in High Energy Physics ?Department of Space Science	05 03 04	80.967 48.036 2.759

Institutions	Scientists	Cumulative Impact Factor
GC University ?Department of Physics ?Salam Chair in Physics	01 01	32.144 147.900
University of Karachi ?Department of Physics ?Department of Applied Physics	10 05	91.147 6.011
Bahauddin Zakriya U niversity ?Department of Physics	07	50.622
National Institute of Silicon Technology	21	36.155
University of Peshawar ?Department of Physics	04	28.080
University of Balochistan ?Department of Physics	02	27.421

Institutions	Scientists	Cumulative Impact Factor
Gomal University ?Department of Physics	13	23.861
NED University of Engineering and Technology ?Department of Physics	01	15.123
University of Sindh ?Department of Physics	04	11.457
Institute of Optronics	03	9.199
Allama Iqbal Open University ?Department of Physics	04	8.894
National University of Science and Technology ?Department of Physics	01	2.095
Shah Abdul Latif University ?Department of Physics	01	2.064
Islamia University (Department of Physics)	01	0.627

Q.4: The areas of Physics on which Pakistan will concentrate in future.
Computational Physics, Lasers and Laser Spectroscopy, High Energy Physics (in Collaboration with CERN, Geneva). I may now add Nanophysics. Applied work

around 5MeV Tandem Van-de-graff accelerator being established at NCP. Synchrotron Radiations particularly building a soft X-ray beam line for SEASME, a synchrotron radiation source being developed in Jordan, of which Pakistan is a founding member. This source will also be used by Pakistani scientists for research in Physics, Chemistry, material sciences and structural biology.

Q.5: What should be the Principal aim of science in the developing world?

The principal aim of science in the developing world is to achieve excellence in certain areas of science. Obviously we cannot compete with the fundamental science of the developed World, but we can take part in it through collaborative arrangements with big centers of Physics in the West, like CERN in Geneva, Abdus Salam ICTP at Trieste. The science-technology chain is becoming shorter and shorter, with the result that a scientific discovery becomes utilized faster in technology than it used to be. Thus it is essential that the developing world should at least be aware of what is happening at the Frontiers of Science. This they can do only if at least some percentage of scientists take part in it, through research, so as to further our scientific insights and to build new technological applications on them and above all to produce new generations of researchers.

One should also not forget that the training which a physicist gets is superb, particularly to analyze a problem so as to take care of all the important factors in that problem and attach to each its due weight. This training is useful when a physicist is called upon to work, either in an industrial or technological enterprise or some other projects of national importance. Anyway, economic development and the role of scientists in this development is a somewhat complex problem.

Q. 6: Should the developed world do more to support science in the developing world?

Yes, the developed world should do more to support science in the developing world. As Prof. Salam has said "Scientific Knowledge is a shared heritage of all Mankind; East and West, South and North has all equally participated in its creation in the past, and, we hope, they will in future. This joint endeavor in science is one of unifying forces among the diverse people in this globe". I may mention that CERN in Geneva is setting a good example in this respect, as I pointed our earlier. To conclude; we have seen that Physics in Pakistan is concentrated at a few places and suffers from the problem of aging. Nevertheless one may mention the following

Achievements:

- ¾ One Nobel Laureate, Abdus Salam
- ¾ Some physicists who have made some international impact, exemplified by their citations
- ¾ Produced good students who have done well abroad and in the country
- ¾ At least one famous paper with Citations more than 500
- ¾ One famous book: A classic with Citations more than 582; two other books, which have very good reviews internationally.

¾ Played major role in National Security.

Main deficiencies

- ¾ Sustainability not achieved
- ¾ Age factor: lack of continuous addition of bright young people
- ¾ Compromise on quality
- ¾ Still Physicists are in small number

Let me end by quoting Robert J. Oppenheimer, “We have all of us, to preserve our competence in our profession, to preserve what we know intimately, to preserve our mastery. This is, in fact, our only anchor in honesty”. At least physicists of my generation followed to some extent what Oppenheimer said.

PHYSICS PROGRAMS: AN OVERVIEW OF EMERGING TRENDS

M. Ashraf Chaudhry, S.A. Hayat, R.Raza
COMSATS Institute of Information Technology
Lahore Campus, Lahore - Pakistan

ABSTRACT

Although Physics is one of the most fundamental of all the sciences, yet it is considered as a dry and difficult subject by many of our young prospective students. Rousing interest and motivation can refute this myth. The soft image of physics can be built up if we could make people realize that its study imparts skills and habits that may be helpful in solving multifaseous problems related to science, industry, management and technology. This role can be successfully met through offering physics-programs / courses in a variety of ways. This is what is being adopted by top-class institutions all over the world.

INTRODUCTION

Physics is the science that describes how the physical world works. It is perhaps the most fundamental of all the sciences. It is an exciting and wide-ranging discipline, which occupies the central position amongst the natural sciences, engineering and technology. Physics is at the basis of nature and is involved in everything around us. The work of physicists has a massive impact on the quality of life, through the design, evaluation and manufacture of a multitude of essential goods and processes, industrial and household materials, medical technologies, laser processing, sensors, and advanced materials with specific properties for modern technology. Rapid advances in high-technology areas, such as laser-systems engineering, telecommunications, optoelectronics or medical applications, demonstrate the unique importance of Physics for our lives and the imagination of Physicists.

It is expected that, in this century, the quality of life will continue to improve through the innovative work of Physicists. Accordingly, there will be strong demand for skilled Physicists of all specialties, to be involved in developing better communication systems, improved materials, alternate energy-sources, and in ensuring a cleaner environment.

Physics is important, not only as a subject in its own right, but also as an essential element in all other natural sciences, engineering and technology. Physics is at the heart of almost every facet of modern life and, as such, physics education is a preparation for a lifetime because its study instructs a person in the art of critical and incisive thinking, how to pose questions and how to solve problems. In addition to that, there is also a great deal of enjoyment and satisfaction to be derived from an

understanding of the most recent developments in Physics.

CAREERS IN PHYSICS

Young persons trained in physics acquire a set of skills that makes them valued employees in many settings. They have always been in great demand, and that demand increases further as technology comes to play an increasing role in society. Physics is so central in the cluster of scientific subjects that physicists are readily employed to shoulder a variety of responsibilities. Many physicists work in research laboratories, in industry, in universities, and in national laboratories. Some join teaching-careers in high schools, colleges, and universities, helping to inspire and shape the next generation of scientists and to nurture an appreciation of science and its importance to society. Others can be found in hospitals, the military, oil fields, power plants, in the astronaut corps, in museums, in patent-law firms, and in management positions in business and government.

A large number of physics graduates continue in basic research. This type of work extends our understanding of the fundamental laws that govern the origin, evolution and ultimate fate of the physical universe. In case of applied physics research, efforts are made to use the fruits of basic research to accomplish specific human objectives, such as the development of better communications, new medical diagnostic tools and other technologies for the service of mankind, or new energy sources. Physicist can also work in the area of computer-modeling and simulation where they may be utilizing their energies in developing complicated computer-algorithms, to visualize how systems behave in various situations.

A reasonable number of physics graduates are joining financial institutions, like banks and insurance companies, while some are working as managers in industrial units, or managing their own companies.

NEED TO SHOW FLEXIBILITY IN OFFERING COURSE/PROGRAM

There are a number of options available to physics graduates as far as jobs and careers are concerned. This wide range is possible due to the fact that the physics role is a central one in the study of other areas of human endeavor, such as science and engineering.

- A flexible first degree in physics would enhance and ensure maximum job-opportunities to its graduates, because the study of Physics develops theoretical and practical abilities that combine sound mathematical and experimental expertise with the ability to grasp new concepts, to analyze, correlate and solve problems, to work in a team with others and to think critically and creatively. Equiped with such a variety of skills, physics graduates shall be able to apply their expertise to a wide range of familiar and unfamiliar challenges in every career. Furthermore, a flexible physics-program that allows one to take course from other

subject(s) would augment their skills to enable them work more confidently in areas which are not directly related with physics.

- It is now common for people to have several very different careers during their life.
- Physics can be taken as a major component of several combined degrees. These degrees enable students to match Science or Advanced Science with another field of study, opening up an even broader spectrum of career-opportunities.
- Physics is becoming increasingly interdisciplinary, as physicists work with mathematicians, engineers, chemists and biologists, in order to understand and solve a wide range of problems confronting society.
- Last but not the least, the Physics Courses must have the largest range of options and variety to attract the largest group of students.

EMERGING TRENDS IN OFFERING PHYSICS PROGRAMS

Many universities are offering physics as a single program. However, there are examples where either a concentration (emphasis) is offered in a particular field of physics or any other subject, or a combined degree program is available for taking physics with any other subject. In such combined degree programs, both the subjects are taught to such an extent that higer education can be obtained in either of the two because both subjects are covered quiet extensively. To make this point more clear, some of the course-offerings suggested in various universities of America, Australia and United Kindom are presented here.

HARVARD UNIVERSITY, USA

- Physics
- Chemistry Physics,
- Physics-Mathematics,
- Physics-Astronomy,

and

- Physics-History of Science
- Physics with Biophysics
- Physics and Teaching

Physics with Certificate

- Physics with Teacher Certification in Physics
- Physics with Teacher Certification in both Physics and Chemistry

PRINCETON UNIVERSITY, USA

- Physics
- Physics with Biophysics Certificate
- Physics with Premedical Requirement

CALIFORNIA STATE UNIVERSITY, FULLERTON

- Physics,
- Medical Physics
- Physics and Astronomy
- Engineering Physics
- Physics with Computer Science
- Physics with Business Studies

Combined Degrees

- Commerce/Science,
- Science/Law,
- Science/Arts,
- Science/Education,
- Science/Engineering

COLUMBIA UNIVERSITY, USA

- Astrophysics
- Biophysics
- Chemical physics
- Geophysics

UNIVERSITY OF NEW SOUTHWALES, AUSTRALIA

- Physics
- Physics with Astronomy
- Physics with computer Science
- Medical Physics
- Engineering Physics

Combined Degrees

- Science / Law
- Science / Commerce
- Science / Arts
- Science / Education
- Science / Engineering

QUEEN MARY UNIVERSITY, LONDON, UK

BSc (3 years Program)

- Physics

- Astrophysics
- Astronomy
- Theoretical Physics
- E-Science
- IT-Science
- Natural Science
- Physical Science
- Physics and Electronics
- Physics and Computer Science
- Physics with Computing
- Physics and Materials Science
- Physics and the Environment
- Physics and Economics
- Physics with Business Studies
- Physics with Finance
- Mathematics and Physics

MSc (4 years Program)

- Physics
- Astrophysics
- Astronomy
- Theoretical Physics
- Physics and Electronics

UNIVERSITY OF YORK, UK

- Physics
- Theoretical Physics
- Physics with Computer Simulation
- Physics with Astrophysics
- Physics with Business Management
- Physics with Philosophy
- Physics with Education

UNIVERSITY OF SUSSEX, UK

- Physics
- Astrophysics
- Physics with Mathematics
- Theoretical Physics
- Physics With Management Studies
- Physics with American Studies
- Physics with Education Studies
- Physics with French, German, or Spanish

UNIVERSITY OF WALES, ABERYSTWYTH, UK

- Physics
- Physics With Atmospheric Physics
- Physics With Planetary And Space Physics
- Physics / Computer Science
- Space Science And Robotics
- Physics With Business and Management
- Physics With Education
- Physics With French
- Physics With German
- Physics With Spanish

BIRMINGHAM UNIVERSITY, UK

- Physics *with* Medical Physics
- Physics *with* Business Management

BATH UNIVERSITY, UK

- Physics
- Applied Physics
- Physics with Computing
- Mathematics and Physics

BLOOMSBURG UNIVERSITY,GERMANY

- BS Physics
- BS Health Physics
- BS Electrical and Electronics Engineering Technology
- BA Physics
- BS. Ed. Physics- Secondary Education

UNIVERSITY OF INNSBRUCK, GERMANY

- Applied Physics
- Medical Physics
- Astrophysics
- Meteorology and Geophysics

OAKLAND UNIVERSITY, GERMANY

- BS Physics
- BA Physics
- BS Medical Physics
- BS Physics: Secondary Teacher Education Program (STEP)
- The Master of Science in Physics

UNIVERSITY OF SCIENCE AND TECHNOLOGY OF CHINA, CHINA

Undergraduate Programs

- Chemical Physics
- Modren Physics
- Astronomy and Applied Physics
- Physics with Mathematics
- Condensed Matter Physics
- Optical Information Science and Technology
- Microelectronics and Solid State Electronics

Graduate Programs

- Condensed Matter Physics
- Optics
- Physical Electronics
- Microelectronics and Solid State Electronics

PEKING UNIVERSITY, CHINA

- Physics (BS)
- Geophysics
- Atmospheric Science
- Space Physics
- Astronomy
- Nuclear Physics and Nuclear Technique

Harbin Institute of Technology, China

- Material Physics and Chemistry
- Applied physics

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY, CHINA

Department of Physics and Materials Science

- BSc(Hons) in Applied Physics
- BEng(Hons) in Materials Engineering
- MSc in Materials Engineering
- Nanotechnology

REFERENCES

Websites of relevant Universities.

DEVELOPMENT OF SOLID-STATE PHYSICS IN PAKISTAN

N. M. Butt
Scientist Emeritus, Pakistan Atomic Energy Commission,
Islamabad - Pakistan

ABSTRACT

The development of research in Physics started in 1948 with the immigration of Prof. Rafi. M. Chaudhri to Pakistan. He was a well known Atomic/Nuclear Physicist and a student of Rutherford at the Cavendish Laboratory of the University of Cambridge, U.K. He did his Ph.D under Rutherford's supervision in 1932. At the time of creation of Pakistan, Prof. Chaudhri was Head of Physics Department at the University of Aligarh in British India and opted to migrate to Pakistan. He was appointed as Professor and Head of Physics Department at the Government College Lahore, Lahore. It was Professor Chaudhri who started the tradition of research in Atomic and Nuclear Physics in Pakistan. Although his main emphasis of research was not in solid-state physics, but he indirectly conducted some research on the "radiation effects of on solids" using the high-energy protons from the 1.2 Mev Cockcroft-Walton nuclear accelerator, installed at the High Tension Research Laboratory, Government College, Lahore, in 1954. Since there was no solid-state physics researcher at the time in Pakistan, only some teaching on related topics of thermodynamic behavior of solids, in particular the area of Debye Theory of Solids, was taught as a basic course of M. Sc. Degree Physics. This program, of course, forms the basis of lattice dynamic research of solids.

The research in solid-state physics was infact initiated in Pakistan when the Ph.D. qualified scientists of the Pakistan Atomic Energy Commission returned to Pakistan, in mid 60's. The field of neutron diffraction and scattering from solids, the radiation-damage studies in solids using methods of electron microscopy, electrical resistivety in solids, etc, were initiated at PINSTECH, and later in the 70's when the Physics Department at Q. A. University (then Islamabad University) became operative, the research in solid-state physics in the area of semiconductors, thermal properties of Solids and Magnetic Properties of Solids etc. was initiated there. So far over the years, several international research papers have been regularly published by Pakistani solid state physicists and several conferences, local and International, have been organized in Pakistan.

Further, in early 70's, a specific Center for research in solid-state physics was initiated with the funding of the Federal Government at the campus of the Punjab University, Lahore. Some of this research is described in this paper. Some other steps such as holding conferences on the subject, establishment of related research-centers, and inviting foreign solid state physicists to Pakistan etc. are also mentioned. All of these steps amounted to

the development of solid-state physics research in Pakistan, as we see today. The historical journey through these steps are briefly described in this paper and future trends would be suggested.

INTRODUCTION

After the birth of Pakistan in 1947, there was a serious shortage of Physics-teachers in Pakistan due to the emigration of Hindu professors to India. Only a few Muslim professors of Physics, having Ph.D degrees, were available and they could be literally counted on fingers.

Therefore, not only the teaching of Physics at the university-level was in precarious condition at the time, the Research in Physics was infact non-existant. The solid physics, as such was not even known.

In 1948, Professor R. M. Chaudhri migrated from Aligarh University, India to the Government College Lahore. He was a known researcher in Atomic and Nuclear Physics and not only teaching in Physics got a good start there but he also initiated the research in Atomic Physics mostly based on discharge through gases, a prominent field of research at the time. He also established the Nuclear Physics research mainly on the fabrication and study of Nuclear detectors and in 1954, established the 1.2 Mev Cockcroft-Walton Nuclear Accelerator at the High Tension Laboratory of Government College. This accelerator, one of the latest in the region, was used for study of Nuclear Reactions and impact of Nuclear radiation (protons in fact) and positive ions on solids. These studies concentrated on a new phenomenon at the time where the electromagnetic radiation was emitted as a result of impact of high energy protons and positive ions on solid surfaces like Aluminium and here we heard for the first time the research studies involving solids, though it could not be regarded as 'Solid State Research' in the real meaning of the term today. A series of papers were published in this area in prestigious journal, Nature.

On the teaching side in the mid 50s, Debye Theory of solids were taught in the subject of thermodynamics, which could be regarded as a subject of Solid-State Physics as well. Professor Tahir Hussain taught us this subject in 1955 during our M.Sc. This subject in the later years of late 50's and 60's developed into the well known branch of Solid-State Physics with the title "Lattice Dynamics", dealing with the study of vibration of atoms in solids, particularly crystalline solids, which contributed to the knowledge of crystallography, a subject of great practical applications. Mainly investigations were made using experimental methods of X-Ray and neutron-diffraction in 50's and 60's and later were supported by Mossbauer gamma-ray diffraction in late 60's and 70's.

The subject of study of crystalline-solids using diffraction methods became the central part of my research career starting from early 60's till later years and this was how the subject of solid-state physics using Nuclear Methods in fact became essential part of

my life.

RESEARCH IN SOLID-STATE PHYSICS AT PINSTECH: THE INITIATION IN PAKISTAN

While we are discussing the development of solid state physics in Pakistan, I think it is pertinent to mention some of the names, particularly belonging to different areas of solid-state physics and that of course does not mean that a number of others who may not be referred, have not contributed to the solid-state physics of Pakistan.

After my Ph.D in 1965 in Mossbauer gamma-rays diffraction from crystals, in view of the Swimming Pool Reactor installation in Islamabad at PINSTECH by the Pakistan Atomic Energy Commission (PAEC), I was, immediately after Ph.D completion at the Birmingham University in UK, sent by PAEC for one year post-doc training in Germany at the famous Nuclear Research Centre at Karlsruhe. The area of Neutron Diffraction and Scattering from solid. This training was useful for initiating research-programmes at the 5MW (at the time, now 10 MW) Swimming Pool Research Reactor at the Pakistan Institute of Nuclear Science and Technology (PINSTECH), soon after my arrival in October 1966.

The Neutron-Diffraction Group, established by Dr. N. M. Butt in 1967 is viable and well known and has published a number of research papers over the years in international journals in the field of solid state physics using the technique of Neutron-Scattering and Diffraction. Later on, well known physicists like Dr. Mansoor Beg, Dr. Q. H. Khan and Dr. Javed Bashir led the group effectively in these years. Important publications, using the triple-axis Neutron-Spectrometer, installed at the PINSTECH reactor, in the area of phonons in crystals and Debye-Waller Factors of Crystalline Materials, were introduced in famous journals abroad.

With the return of Dr. F. H. Hashmi, Dr. K. A. Shoaib to PINSTECH after their Ph.Ds, the group on radiation damage in solids was established. The main programme was to study the defects in solids caused by neutrons or ions. The planned technique was of use the Electron-Microscopy. The laboratories for which were planned and the Electron Microscopes (Transmission and Scanning) were installed in 80's. The group published a number of papers on the mechanical properties of solids affects by atomic-defects on grain-boundaries. In addition, these laboratories have served other national requirements, such as the study of causes of mechanical failures of parts of aero-planes of Air-Force causing accidents.

PINSTECH, apart from Solid-State Physics, has contributed research in materials science, akin to the subject of Solid State Physics using the Transmission Electron Microscopy. Further, the impurity in solids using scanning electron microscope has been one of the well-used area in the study of solids. These impurities lead to the study of defects in solids, complimentary to such studies using the transmission electron microscopes. The Mossbauer Spectroscopy work initiated by Dr. N. M. Butt, which

made extensive progress in investigating magnetic solids, corrosion of iron, ionic distribution in magnetic solids, etc. has been published. PINSTECH continues this research todate. A standard research in the Solid State at PINSTECH was also done in the area of Solid State Nuclear track detection, mainly acquiring information on damage in plastic solids when nuclear particles pass through these materials. In this technique, considerable research leading to proliferation in research papers has made PINSTECH one of the leading laboratories of the world. Dr. Hameed A. Khan who established this area at PINSTECH, is one of the top scientists in the field and has brought out number of publications in a variety of international journals.

PINSTECH gave a boost to Theoretical Solid State Physics particularly in the area of computer simulation applied to study the transport properties of solids, static and dynamic properties of long chain polymers, and catalytic surface reactions etc. This area led by Dr. A. Sadiq and Kh. Yaldram, made good impact on theoretical research on international level, particularly in collaboration with leading laboratories of Germany and France.

In later years, the study of high temperature superconductivity of $Yba_2Cu_3O_2$ and the structure of solids (KBr, KCl, mixed Alkali Halides) using x-ray and neutron diffraction has been an active area of Solid State Physics research. In one of the samples containing several elements like Bi, Pb, Sb, Sr, Ca, Cu and O, a transition temperature $140^{o}K$ was also observed (C/O Dr. J. A. A. Khan). This temperature was one of the highest at the time. The neutron diffraction studies of cellulose Polymer and Alkali Halides were extensively studied and notable research on Debye-Waller Factors and texture of materials of international recognition was done. Pakistan (Dr. N. M. Butt) was thus put on the panel of correspondents of the well known international magazine the “Neutron News”. Later, work on correlation of micro and macro properties of crystals set new trends and was highly cited across the world.

Recently, research on structure of solids using Synchrotron Radiation source at Elettra, Trieste, Italy was done as a result of acceptance of the project of the PINSTECH Materials Research Group (C/O Dr. M. Javed Akhtar and Dr. J. Bashir). Some work on the development of special laser quality crystals led to the growing of Nd-YAG crystals (C/O Dr. S. Jalal Bokhari) used in the laser technology. These high purity crystals have been grown indigenously and made Pakistan independent of import from abroad. The development of indigenous instrumentation for Solid State Research led to the fabrication of x-ray powder diffractometer of as good precision as available from the imported instruments (C/O Mr. M. Akhtar). It is important that such instruments should be commercialized to substitute import of such an expensive equipment which can be supplied to local laboratories needing powder diffraction of solid materials which is of common need of several laboratories in Pakistan. Over the years (1967 – 2003) out of about 1200 research papers published by PINSTECH in international refereed journals about 200 (~ 17%) form the share of Solid State Physics papers, and claiming of course the major thrust as compared to other

specialties in physics papers. In brief, PINSTECH has contributed to the indigenous high quality research in various areas of Solid State Physics.

SOLID STATE PHYSICS AT THE QUAID-I-AZAM UNIVERSITY

The other major contributor to Solid-State Physics are mainly four experimental groups and one theory group at the Physics Department of the Quaid-i-Azam University (QAU). The main areas of experimental Solid-State Physics at Q. A. University are semiconductor physics introduced by Prof. Zafar Iqbal, structure properties of solids (led by Prof. Farid A. Khawaja), thermo physical properties introduced by Prof. Asghari Maqsood and the magnetic properties of solids introduced by Prof. Khurshid Hasanain. The theoretical Solid-State Physics was led by Prof. A. H. Nayyar on magnons – phonon interaction studies of rare-earth magnetic materials and calculation of correlation functions and structure factors of Heisenberg Ferro and anti-Ferro magnets in one and two dimensions. Studies of soliton like excitations in one – dimension Ferro magnets has been popular work by this group. The semiconductor physics centered around Si, and III-V compounds such as GaP, GaAsP, Al Ga As and InP. A number of deep-level systems in n-type Si were studied leading to publications in international journals. The structure properties physics mostly was concentrated on electronic structure, order-disorder phase transitions and stress-strain analysis using mainly x-ray diffraction method. The theoretical work of this group was done on short range order in binary alloys using pseudopotential theory.

The thermo physical research was mainly concentrated on the development and use of the transient hot strip method to study the thermal transport properties of composites. The ceramics at higher temperatures of (300 - 800 $^{\circ}$K) were also investigated. Some work was also done on high temperature superconductivity and on the preparation of the high Tc materials. The group contributed to growth of single crystal high Tc materials and investigation of their transition temperatures. Earlier research was concentrated on spin glasses like Nd Fe_2, Pr Py ($y < 1$), Gd – Al etc. Magnetic properties of maraging steel in relation to deformation and structural phase transitions were also studied. Recent research on Colossal Magnetic Resistance (CMR) using magnetometers and Mossbauer Spectroscopy has been done and current research introduces work on nano-science using Iron particles leading to technological applications of Fe-nano-particles as sensors for diseased cells. Q. A. University Solid State Physics has contributed major share in producing trained manpower in Pakistan in the form of M. Phil. and Ph.D. graduates in the areas briefly mentioned above. It is pertinent to mention that out of the 78 Ph.D. graduates produced by the Physics Department of Q. A. University over the period (1971 – 2005), 15 Ph.D. graduates produced were in Solid State Physics, thus forming about 20% of the Ph.D. (Physics) produced during this period. [Ref: “Physics at Q. A. University”, 2005 Physics Dept. Q. A. University, Islamabad].

CENTRE FOR SOLID-STATE PHYSICS, LAHORE

In early 70's, the Federal Government developed a scheme of centres of excellence in various sciences. Under this programme, a centre for Advance Solid State Physics was setup at the New Campus of the Punjab University in Lahore. Late Prof. Muzaffar Ali Shah was appointed as the Founding Director of this centre (the author was offered this position and the Chairman PAEC, rightly then, did not allow my release because of the forthcoming important laboratories on Neutron Diffraction to be established around the 5MW Swimming Pool Research Reactor at PINSTECH. The author however remained in touch with the centre for several years being on the Advisory Board of the Centre). This Centre got a boost under the Japanese Aid-Programme and latest Solid State experimental equipment was provided to the centre. This included the crystal growing, X-ray diffraction, the high temperature furnaces, the electron microscope with Auger – electron studies of surfaces etc.

The centre contributed to the training of M. Phil. Graduates in Solid State Physics as well as research papers in the areas suitable to the experimental equipment. The research publications got boost due to publications of theoretical Solid State Physics on LEED by Dr. Nazma Masud and later by experimental publications on surface physics by Dr. M. Suleman. Publications in the area of electrical properties by Dr. Fateh Mohammad, High Temperature Superconductors by Dr. Saadat Siddqui and variety of papers on X-ray diffraction and magnetic studies were also published by other authors. Theoretical papers were also produced by Dr. Tariq Abdullah. However, unfortunately the Solid State Centre could not maintain the progressive level of research publications in recent years particularly after the death of Dr. Suleman and hence needs a special attention for its support and meritable management by the Government.

SOLID-STATE PHYSICS AT GOVERNMENT COLLEGE, LAHORE

A good amount of research on Solid State Physics mostly concentrating on Solid solutions and metallic alloys dealing with the mechanical properties of yield strength, crack propagation, defects in alloys, fatigue and creep studies were carried out by Prof. M. Zakaria Butt and his students leading to a number of highly cited international publications. In addition, a number of M. Phil. graduates were produced at the Physics department of the Government College.

The transfer of Prof. Zakaria Butt to administrative position has led to the drastic reduction of Solid-State Physics research at the Government College and a great setback to the Solid-State Physics of this area in Pakistan. The management needs to take such decisions with great sense of care as the establishment of research to be seen at the international standards takes years to establish but takes little time to diminish by such decisions. The managers have to see that over the period, viable research groups need to be established so that in case the movement of a scientist is essential, the research level does not get a drastic setback.

OTHER PLACES

Solid State Physics Research publications from other places like Institute of Silicon Technology University of Peshawar where Dr. M. Ali Khattak got trained in Solid State Theory mainly concentrated on its teaching and at University of Karachi has been nominal and sporadic and has therefore not been covered here.

RELATED SCIENCE: MATERIALS PHYSICS

The area of Materials Science is akin to the Solid State Physics in the sense that the experimental equipment is mostly common for the studies of both these areas, whether these are electron microscopes, X-Ray or neutron diffractometers, mossbauer spectrometers or electrical or magnetic property study equipment.

The selection of problems varied in the sense whether the investigations are related to solid state or Materials Science.

Such facilities existed at PINSTECH and in the A.Q. Khan Research laboratories at Kahuta. Some research attempts on Materials Science were made at the UET Lahore and at the PCSIR laboratories. However, though the equipment is mostly similar, the Materials Science needs an extensive work and time to discussion.

OTHER MEASURES OF BOOSTING/SUPPORT TO SOLID-STATE PHYSICS IN PAKISTAN

The Solid-State Physics Development in Pakistan has got progressed due to some of the important other supporting activities which need to mention briefly. These are:

I. International Cooperation

Various research groups whose work has been described above, enhanced because of international research cooperation. This included the visit of foreign scientists to Pakistan as well as the visit of Pakistani scientists to the research centres abroad.

In the area of neutron diffraction, PINSTECH was benefited by the visits of Dr. Blinoski of Poland and Dr. Stig Rolandson, a Swedish scientist for about a year in early 70's. PINSTECH scientists also made visits to Reactor Centre at Karlsruhe (Germany) Oak Ridge National Laboratory (USA), Riso Centre (Denmark) and Royal College Research Reactor at Stockholm (Sweden).

The Radiation Damage Group at PINSTECH benefited from the cooperation of Research centre in Karlsruhe (Germany) whereby the Pakistani scientists visited that centre under scientific cooperation. The group also benefited from the visit of Prof. Shaheen of USA to PINSTECH. The scientists were also benefited by cooperation with France (University of Strassbarg (C/O Prof. M.A. Khan) and university of Mainz (C/O

Prof. K. Binder).

The Q.A University benefited from the visits of Prof. M. Wortis USA (in 70's) and Prof. S. Gustaffson of University of Goteborg, Sweden (in 80's).

II. Aids and Grants

Solid State Physics of Pakistan has also got great advantages through foreign aid and grants.

The Q. A. University and the Solid State Physics centre at Punjab University Lahore received major equipment from Japan through educational Aid programmes.

PINSTECH got Neutron spectrometer from Research Centre of Karlsruhe worth $100,000/- under German donation through Alexander von Humboldt Foundation (C/O Dr. N. M. Butt).

PINSTECH also benefited from various grants and aid from the International Atomic Energy Agency (IAEA) for Neutron Scattering research in the recent years. Recently, PINSTECH Scientists were helped by the Synchrotron Radiation facility Elletra, Trieste, Italy after they competed for a project time and were successful in winning time on this SR faculty for the project proposed in the area of Solid State Structure research (C/O Dr. M. Javed Akhtar and Dr. Javed Bashir).

III. Conferences on Solid-State Physics

Lot of developmental benefits for Solid State Physics accrued from the organization of local as well as international conferences which provided ample chances of mutual discussions by the Solid State Physicists.

On the local level, the conferences were arranged by the Pakistan Physical Society and the Semiconductor Society of Pakistan as well as by the Pakistan Institute of Physics.

In 1974, a major international conference on Solid State Physics was held in Islamabad with the funding (US$ 40,000) of US National Science Foundation (NSF). World renowned scientists like B.N. Brockhouse of Canada, (Nobel Laureate 1994), J.M. Ziman, F.R.S. (UK), G. H. Wannier (USA), W. A. Sibley (USA), K. Ehrlich (Germany), A. B. Lidiard (UK), M. W. Thompson (UK) and W. C. Koehler (Oak Ridge, USA) gave lectures on contemporary topics. Solid State Physicists from all over the country benefited from this 10 days interaction with these renowned Physicists from abroad. A conference on Solid State Physics of that level where such a large number of world-known physicists got together at one time has not been held in Pakistan afterwards.

Since 1976, the Nathiagali Summer Colleges have been arranging the lectures of

renowned Solid State Physicists from time to time at their annual summer colleges. In addition to benefits during the summer college, scientific cooperation has been developing thereby greatly benefiting the research in Solid State physics in Pakistan.

Furthermore, Pakistani Physicists have been participating in conferences abroad and making scientific visits abroad under various programmes like DAAD and Humboldt Fellowships (Germany), Commonwealth Scholarships (UK), etc. and thereby bringing new ideas to boost research in Pakistan.

All channels have been benefiting the Solid State Physics Research in Pakistan and this has resulted with quality Physics research in Solid State Physics that we see today.

FUTURE OF SOLID-STATE PHYSICS IN PAKISTAN: NANO-SCIENCE AND NANO-TECHNOLOGY

With ever growing research, the new off shoots, in Science and Technology keep on emerging from traditional areas and giving birth to new names of the emerging Science and Technology. With development of precision tools and equipment used in Solid State Physics, particularly using Electron Microscopes, when the precision has reached to see the atoms and molecules and to handle them in the laboratory, the new area of "Nano-Science and Nano-Technology" has emerged and is influencing all branches of science speedily.

Since the capability to handle and control the atoms and molecules (size of a few nano-meters) is in hand, the enormous application in Biological and Material Sciences, Environmental Sciences, Information Sciences & Technology etc. has emerged. The fact of the matter is that with the evolution of Nano-technology, influence of this technology has engulfed all sciences. Thus today, we see the application of Nano-technology in medicine, Biotechnology, Energy systems, fuel cells, pharmaceuticals, agriculture, various kinds of industry, auto-industry, textile industry, electronics industry etc and in subjects as exotic as control of terrorism and strategic defense in space technology and so on.

NANO-TECHNOLOGY IN PAKISTAN

The vision of researchers in Pakistan has immediately realized the importance of nano-technology and the scientists of Pakistan supported by the Government funding are now paying active attention to take up areas of Nanotechnology with particular need and relevance to Pakistan.

A National Commission of Nano-Science and Technology (NCNST) has already been instituted by the Ministry of Science and Technology (MoST), Government of Pakistan. Before a detailed policy is worked out, the groups which having of course a good track of research relevant to slip over in Nano-science, are being supported by the allocation of Government funds.

These groups in the area of Nano-biotechnology (at NIBGE), quantum devices (optics labs of PAEC), Synthesis & Characterization (at PIEAS), nano magnetism at Q.A. University, Thin films (at CIIT) have already been supported by the Ministry of Science and Technology (MoST) and Higher Education Commission (HEC) funds through the recommendations of the National Commission on Nano-Science and Technology.

Further efforts of NCNST, which has its advisory Members coming from all major scientific organizations and Universities, are in progress to plan national requirements of Nano-science and Technology in Pakistan.

CONCLUSION

This paper is a brief journey through the different stages of development of Solid State Physics in Pakistan. It is of course, does not a full justice to the topic, and considerable material must have been missed, for which I seek apology but, nevertheless this brief recourse gives a fair picture of the developments of the Solid State Physics. It is also a quick peep into window of Nano-Science and Technology and opportunities vastly lying ahead that need to be addressed before it is too late for the very fast growing technology.

ACKNOWLEDGEMENTS

I am grateful to Dr. Zafar Iqbal, Dr. Hasanain and Dr. Aslam Baig for their help in provision of some of the material. I am also grateful to Dr. M. Afzal Sheikh for going through the text of the paper and the suggestions. I am grateful to Director General PINSTECH & PAEC for provision of facility of the office of Scientist Emeritus at PINSTECH (C/O Mr. Abdul Saboor and the other staff).

DEVELOPMENT OF SUCCESSFUL RESEARCH ACTIVITIES IN PHYSICS: A SRI LANKAN EXPERIENCE

M.A. Careem
Department of Physics, University of Peradeniya
Peradeniya - Sri Lanka

ABSTRACT

Physics plays many vital roles in the developmental activities of a country, whether it is developing or developed. Local expertise in Physics is becoming increasingly essential for the developing countries, to get maximum economical advantages from the knowledge-based technologies and emerging technologies, such as nanotechnology. With the aim of enhancing the local expertise in Physics, a research programme on technologically important materials was initiated, almost from scratch, at the Department of Physics of the University of Peradeniya, Sri Lanka, in 1986. This paper outlines the science and technology situation in Sri Lanka and describes the development of this research activity and its successes. Since the commencement of this research programme, the Peradeniya group has produced 14 Ph.D.s and 5 M.Phil.s., and several M.Sc.s, and has published more than 100 research papers in international refereed journals and presented over 200 papers in national and regional conferences. The Ph.D. and M.Phil. Degrees have been offered on sandwich-basis, with several collaborating universities in Europe. These sandwich programmes have been successful not only in producing Ph.D.s and M.Phil.s of internationally recognized standards, but also in containing the brain-drain of trained Physicists from Sri Lanka to some extent.

1. THE ROLE OF PHYSICS IN DEVELOPMENT ACTIVITIES

Competence in Science and Technology (S&T) is essential for any country, whether it is developed or developing, as the standard of living in a country depends on the degree of expertise that it has in S&T. Development of a country will increasingly depend on its ability to access, comprehend, interpret, select, adapt, use, transmit, diffuse, produce and commercialize scientific and technological knowledge, in ways appropriate to its culture, aspirations and level of development [1]. Therefore, the need for the endogenous competence in S&T is greater in a developing country for the country to be able not only to develop its own S&T base, but also to benefit from technologies imported from the developed world. In order to get maximum benefits and to sustain imported production, methods and technologies must be suitably adopted to fit into the existing social and technological environment of the country. There have been several examples where development projects in undeveloped countries have failed, due to the involvement of foreign experts who are unfamiliar with local situations. Hence, a multi disciplinary knowledge-base, developed through research, is essential

in order to build up an infrastructure and endogenous competence in S&T in a country. Such a knowledge-base with emphasis on Physics, as Physics is the basis for most modern technologies, is also important for a country to be able to plan and implement development strategies efficiently [2].

Physics plays many vital roles in the economic development of a country, irrespective of its status of development. It has a major role in many key-sectors, such as transport, eco-friendly energy production, prediction and modeling of natural disasters and metrological events, monitoring environmental changes, healthcare and sanitation, agriculture and food-production, development and production of new devices and equipment, and the emerging field of nanoscience and nanotechnology. As the economy of the world is shifting from resource based to knowledge-based, the knowledge in Physics is becoming increasingly important. Most of the production of consumer-devices is being shifted from developed countries to low cost factories in developing countries, and the emerging field of nanoscience and the associated nanotechnology are not based on traditional raw materials, but based on materials that can be produced even in developing countries. Therefore local expertise in Physics is essential for the developing countries to get maximum economical advantages form the new trends and emerging technologies. Physics also can address a large number of problems that developing countries have to face and help find cheap and easy solutions for many of them, e.g. production of solar energy, monitoring of urban and rural pollution, medical applications, water purification etc.

To enhance the local expertise in Physics in developing countries, not only the educational facilities needs improvement but facilities for basic research are also needed. Advantages of training in Physics research training include the flexibility to tackle a wide range of problems and to be able to move from one discipline to another. It also provides the ability to solve problems from first principles when standard solutions do not apply.

The problems encountered in Physics research and training in developing countries are acute. Some of the common problems are serious lack of funding, which worsens with the economic situation, lack of private-sector demand, political instability, internal conflicts or wars, isolation of scientists, lack of public awareness, lack of policy and institutional framework for research, difficult or no access to scientific publications, lack of information and communication- technology facilities, etc. In spite of all these difficulties, what has been achieved in the development of research activities in some developing countries like Sri Lanka is commendable. This paper concentrates on the development of research activities in Sri Lanka in Physics-related fields, in general, and describes the building of research capacity in Physics at the University of Peradeniya, in particular.

2. STATUS OF SCIENCE AND TECHNOLOGY IN SRI LANKA

According to the criteria commonly used to rank S&T capacity, Sri Lanka is placed

among the scientifically lagging countries by a World Bank study, and its performance in S&T is poor compared to that of many countries in South and Southeast Asia [1]. The Table-1, which shows science and technology development indicators for a number of countries in South and Southeast Asia, illustrates this.

The numbers of scientists and technicians employed in R&D work in developed countries as a proportion of the population are considerably greater compared to those in developing countries. For example, in Japan the number of scientists and engineers in R&D per million people is 5,085 and number of technicians per million people is 825. In Sri Lanka the corresponding numbers are only197 and 48. In India these numbers are 120 and 102 respectively. According to the data in the table, the human capital needed for successful science and technology development (scientists, engineers, technicians, as percentage of total population) in Sri Lanka is proportionately large or comparable to that in some countries which are perceived to have more successful S&T systems, such as India, Malaysia and Thailand. However, with respect to the outputs of the S&T system (publications, high technology exports,

Table - 1: Science and Technology Development-Indicators for Selected Countries

Country	Scientists and Engineers in R&D per million people 1996-2002*	Technicians in R&D per million people 1996-2002*	Scientific and Technical Journal articles 2001	Expenditure on R&D % GDP 1996-2002*	High-technology exports		Royalty and License fees		Patent Applications filed	
					$ millions 2003	% of manufact-ured Exports 2003	Receipts $ million 2003	Payments $ million 2003	Residents 2002	Non-Residents 2002
Bangladesh	(52)	(33)	177	0.03	1	0	0	4	[32]	[184]
China	633	(200)	20978	1.2	107543	27	107	35748	40346	140910
India	120	102	11076	0.8	2292	5	29	356	220	91704
Indonesia	(182)	---	207	(0.07)	4580	14	---	---	0	90922
Japan	5085	(827)	57420	3.1	105454	24	12271	11003	371495	115411
Korea, Rep.	2979	(318)	11037	2.5	57161	32	1325	3597	76860	126836
Malaysia	294	57	494	0.7	47042	58	20	782	[50714]	[71036]
Pakistan	88	14	282	0.2	120	1	8	36	0	1168
Philippines	(157)	(22)	158	(0.22)	23942	74	2	273	0	81697
Singapore	4352	381	2603	2.2	71421	59	197	3334	511	93748
Sri Lanka	197	48	76	0.2	19	1	---	---	0	88379
Thailand	289	116	727	0.2	18203	30	7	1268	1117	4548
U.S.A.	4526	---	200870	2.7	160212	31	48277	20049	198339	183398

* Data are for the latest year available
Source: World Bank Development Indicators 2005; ( ) 1987-97 data; [ ] 1998 data

royalty & license fees, patent applications etc) Sri Lanka is considerably behind these countries. For example, in 2001 the number of scientific publications from Sri Lanka was a mere 76, which is the lowest among the countries listed in Table-1.

This poor performance is not due to inferior quality of scientists in Sri Lanka, but is due to various difficulties they face in carrying out R&D work. Some of the reasons for poor performance in S&T of Sri Lanka have been identified, at a recent workshop conducted by National Academy of Sciences of Sri Lanka [3], as follows:

- Low overall expenditure on R&D
  Sri Lanka spends only about 0.20 % of its Gross National Income (GNI) on R&D, as against 3% of GNI by developed countries.
- Low investment in S&T by the state sector
- Low private-sector expenditure on S&T
  In developed countries, the private sector accounts for over 60% of total R&D expenditures; but in Sri Lanka, it is only about 1.5% in 2001.
- Poorly developed high-technology production
- Inappropriate policy-environment
- Brain Drain
- Lack of efforts to promote high-technology industries

The possible remedies for overcoming these difficulties are mentioned in Reference-3.

Although Sri Lanka contributes nearly 0.2% of its GNP for R&D, a major part of this modest expenditure goes largely to pay salaries and allowances of staff, with relatively little going to finance the actual implementation of R&D programmes. Majority of the available research-grants go to applied-research areas, such as agriculture, healthcare, life and chemical sciences The real contribution going to Physics research is very small, and can be estimated to be around US$ 100,000 per year, which corresponds to 0.0006% of GNP. The low amount allocated to Physics is because it is considered as one of the fundamental fields, rather than a field useful for the economic development.

3. PHYSICS EDUCATION AND RESEARCH IN SRI LANKA

Proper university system in Sri Lanka was initiated in 1942, with the establishment of University of Ceylon by amalgamating the existed University College and the University Medical College. Physics was taught as a subject in the Faculty of Science, situated in the Colombo campus of the University since then. However, no expertise and facilities were available for majoring in Physics and for postgraduate studies at the beginning. Physics Special (major) degree-programme was made available only from about 1945. Until then, the majoring and postgraduate degrees in Physics were obtained abroad, mainly from the universities in the United Kingdom. With the commencement of the Special Degree programme, 3-5 physicists were trained each year. As the demand for science education grew, a new Faculty of Science with a well

equipped Physics Department was established in 1961 at Peradeniya. However, the new Department was able to offer Physics major programme starting form 1968 only. The two campuses in Colombo and Peradeniya were made independent and named as University of Colombo and University of Peradeniya in 1967.

At present, there are 13 universities in Sri Lanka including one Open University. Faculties of Science exist in all these universities, except in the University of Moratuwa, at which only a Physics Unit is available. Physics is taught as a separate subject in 10 of these universities in the Faculties of Science. Generally, Physics is offered as one of the three subjects for the 3-year General Degree course or as a Major subject for the 4-year Special Degree Course. A large number of students, about 100 students per year in each of the 10 universities, offer Physics as one subject for their 3-year General Science Degree course. Around 10 students per year study Physics as a major subject in each of the 8 universities that offer the Special Degree Course. The Science Degree courses offered by Sri Lankan universities are of good standard and comparable to those offered in many developed countries. Large number of our Physics major graduates, and some of the General Degree graduates with Physics as a subject, get admission to US universities after competing with students from other countries and nearly all of them not only complete their degrees successfully but contribute to the R&D of US significantly.

Even though, the undergraduate programmes were maintained up-to-date from the early days, no serious effort was made in developing the postgraduate programmes in Physics. During the late 1940's and early 1950's, there had been some research activities on cosmic rays and elementary particles at the University of Colombo and on ionosphere at the CISIR (now ITI) in Colombo. Later on, in the 1960's, there was an effort to carryout research on geomagnetism in Colombo. However, these activities did not continue due to various difficulties, such as inadequate qualified researchers, isolation and heavy teaching duties. The only research activity that was continued, without interruption, is the solar-cell material research initiated by Prof. K. Tennakone in the late 1970s (first at University of Sri Jayewardenepura, then at University of Ruhuna and later at the Institute of Fundamental Studies). This activity resulted in many international publications and enabled Prof. Tennakone to become a scientist of international repute. He is at present heading the Institute of Fundamental Studies in Sri Lanka, at which a number of frontier-research activities in Physics are being carried out. In 1977/78 a research programme on Atmospheric Physics was initiated in the University of Colombo with financial support from the International Programme in the Physical Sciences (IPPS) of the Uppsala University, Sweden. Later on, another research-programme on Molecular Desroption was also started in Colombo in 1981, with IPPS support. These two programmes are still continuing with successful outputs. In addition, there are several research activities on a smaller scale at universities of Kelaniya, Sri Jayewardenepura, Ruhuna and Jaffna. These activities mainly concern semiconductors, solar cells, geophysics, solar energy, new materials and superconductivity.

The research activity in the University of Peradeniya, on which this paper is based, was initiated in 1986 with financial support from IPPS. The activity at the initial stage was concentrated only on Solid Electrolyte materials, but now includes a variety of technologically important novel materials involving polymer- electrolytes, conducting polymers, ceramics, semiconductors, etc.

4. DEVELOPMENT OF PHYSICS RESEARCH AT THE UNIVERSITY OF PERADENIYA

The Department of Physics at the University of Peradeniya was started as a sub-department affiliated to the Colombo Physics Department, with only a few qualified staff members in 1961. As such, the staff had to concentrate on developing the undergraduate programmes, mainly the three-year General Degree programmes. Students found eligible for Physics major degrees, at the end of the first-year qualifying examination, were sent to Colombo. No significant research activities took place at Peradeniya during the early period.

Because of the growing demand for Physicists, a special degree-programme in Physics was started at Peradeniya in 1968, with the help of two visiting British lecturers sponsored by the British Council. A total of 10 fresh general-degree graduates, including myself, were admitted, to follow an additional two-years to complete the Physics special degree. Of the 10 admitted two gave up the course halfway and eight completed the degree successfully in 1970. The first six, including myself, who have obtained First Class or Second Class Upper Division were absorbed into the Department as Assistant Lecturers and sent abroad for postgraduate training. The newly trained staff returned to the Department, one by one, starting from 1976 and the staff strength of the Department continued to improve from that time onwards. The Department at present consists of 3 Professors, 1 Associate Professor, 10 Senior Lecturers (all with Ph.D. training in various areas of Physics), and 1 Probationary Lecturer plus 6 Temporary Assistant-Lecturers all with Physics major degrees. The Department, now, offers a number of courses in Physics for the General and Special Degree students, conducts an M.Sc. Degree course in Physics of Materials and offers a variety of research projects for M.Phil. and Ph.D. students.

In the early 1980's, (with the staff situation improved) the Department began to introduce short-term research projects as part of the undergraduate programmes and offered an M. Sc. Course in Physics (by Course work) with a 3-month research component. Even though the Department had around six qualified staff with Ph.D., most of them trained in Solid State Physics, it was not possible to start any serious research activity due to lack of facilities and funds. In 1983, I came across a fellowship programme offered by the International Seminars in Physics (now IPPS) of Sweden, which allowed post-doctoral training in Sweden with the possibility of receiving follow up support to continue the research at home. At my request, the IPPS offered a fellowship in 1983/84 for me to undergo research- training on Solid State Ionics, an emerging field at that time, at the Chalmers University of Technology at Gothenburg,

Sweden, under the supervision of Prof. Arnlold Lunden. This was the turning point for the Physics research at Peradeniya.

With the idea of continuing the research at Peradeniya, Sulphate-based Solid Electrolytes were identified as the materials for the first stage of research because the materials had good scientific scope and samples for measurements can be easily prepared in Sri Lanka (with readily available chemicals) and the investigations can be carried out with low-cost instruments. A hydraulic press, an Impedance analyzer and a furnace were the instruments needed initially to embark on this research. Satisfied with the progress of the research activity and future plans, the Director of the IPPS visited Peradeniya in 1984 and convinced himself that Peradeniya had the basic requirements, such as sufficient number of academic and technical staff, laboratories, library and machine shop, to embark on collaborative research activities. I returned to Peradeniya late in 1984, and a colleague of mine from Peradeniya (Prof. M.A.K.L. Dissanayake) was immediately sent to Chalmers University under an IPPS fellowship to undergo training and continue the research work at Chalmers University.

In early 1986, following our training, a Solid State Physics research-group was formed at Peradeniya and a research project on Sulphate-based Solid Electrolytes was initiated, with the equipment donated by the IPPS, in collaboration with Chalmers University, Sweden. A research paper, based entirely on the research done at Peradeniya, was presented at the Regional Workshop on Materials for Solid State Batteries held in June 1986 at the National University of Singapore. The first postgraduate student (P.W.S.K. Bandaranayake) recruited to work on the project obtained his Ph.D. degree from the University of Peradeniya in 1991. It took him a little over 5 years to complete his degree, as he had to carry out part of his research work in Sweden on sandwich basis under IPPS fellowship scheme. This was the first-ever Physics Ph.D. awarded by a Sri Lankan University. Dr. Bandaranayke has been absorbed into the permanent cadre of the Physics Department and he is an active young member of the research group at present.

Over the past 20 years the Solid State Physics research group has expanded considerably. Two more major areas, Semiconductors and Ceramics have been included, and the solid-state ionic activities have also been widened to include two major areas: Ionically Conducting Polymers and Electronically Conducting Polymers. Four subgroups have been formed to concentrate on each of the above areas. The entire group as at present consists of 9 senior members with Ph.D.s and 10 M.Phil./Ph. D. students. The group began its experimental work with a high- temperature furnace and an HP 4192A impedance-analyzer donated by the IPPS. But now it has a fairly well-equipped laboratory with several experimental facilities, including X-ray diffractometer, Vacuum coating-unit with sputtering facilities, DSC, Spectrophotometers, etc. While continuing the fundamental research on many new materials, the group also conducts several application-oriented studies, such as polymer rechargeable batteries, artificial muscles with conducting polymers, fabrication of low-cost ceramic bricks, value-addition to raw materials, low cost and

polymer-based solar-cells. The research facilities are also used for the student projects at both B.Sc. and M.Sc. levels.

Because of dedicated hard work, the Peradeniya group was able to attract considerable funds from the IPPS. Over the past 22 years, IPPS has contributed well over 10 M SEK(nearly US $ 1.3 M), in the form of training of senior staff, fellowship to students to do part of research abroad, equipment, support to attend conferences etc. [4]. Having monitored the progress closely, the IPPS has promised to continue its support for the group, until the group can sustain its activities on its own both financially and scientifically. Through its untiring efforts the group has also obtained considerable funds from the European Union (1992-1995), ICTP, National Science Foundation, Sri Lanka, Postgraduate Institute of Science (PGIS), Sri Lanka and University of Peradeniya. The group has established links with a number of research institutions and Universities, both local and foreign, for joint research work and sandwich Ph.D. programmes. Some of the Collaborating Institutions are Chalmers University (CTH) and Royal Institute of Technology (KTH), Sweden, Technical University of Denmark (DTU), Denmark, Aberdeen University, Sheffield Hallam University and Warwick University, U.K, INPG, Grenoble, France, Swiss Federal Institute Zurich (ETH), Switzerland, IIT, Bombay, India and University of Oklahoma, U.S.A.

Since the start of the research programme, the group has published more than 300 research papers, out of which nearly 100 are in peer-reviewed international journals. Also, 14 students from the group have received their Ph.D.s, of which 11 obtained their degrees from the University of Peradeniya under sandwich arrangements and the other 3 has received their Ph.D.s from the collaborating Universities abroad. Five students have completed their M.Phil. Degrees and several students have received Master of Science degrees. All these graduates have been successful in securing employment or in continuing their education. Of the 14 Ph.D.s produced by our group, 8 are employed as academic staff in the universities in Sri Lanka, one is a director of an educational institute, one is a senior researcher at the Institute of fundamental Studies, four are abroad (one employed and 3 are postdoctoral fellows). At present, there are about 75 active Physicists with Ph.D.s in Sri Lanka; probably twice as many stay abroad. Of the 75 Ph.D. holders staying in Sri Lanka, 20 have been produced on sandwich- basis, both at Colombo and Peradeniya. These figures indicate the effectiveness of the sandwich programmes in providing postgraduate training of internationally recognized standard and in containing the brain-drain of trained Physicists from Sri Lanka, to some extent. Nearly 90% of the Peradeniya Physics Major graduates, including all the bright ones, go abroad for higher studies but hardly any of them return to serve in Sri Lanka. But nearly 70% of the graduates trained through our sandwiched Ph.D. programmes have remained to serve the country. Similar results have been reported by the University of Colombo, which is also offering sandwich Ph.D. programmes through IPPS support and produced 12 Ph.D.s in Physics over the past 25 years.

Due to the dedication, interest and careful planning of the activities by the group-members, the group's activities have attracted attention of local authorities. The senior members of the group have been given responsible positions in several research and funding organizations. Prof. Dissanayake and I have been elected as members of the National Academy of Sciences of Sri Lanka. Some of the members have been serving as committee-members in the National Science Foundation, which is responsible for the promotion research in the country. Prof. Dissanayake has been appointed as the director of the Postgraduate Institute of Science (PGIS), a national institute for providing postgraduate degree programmes in Science. I have been serving as a member of the University Grants Commission and recently appointed also as a member of the National Research Council whose main function is to promote research in Sri Lanka by providing incentives for the active researchers in the form of awards and substantial research grants. Some of our members have received President's Research Bonus awards and are serving as members of editorial boards of journals. Many members have been serving as officials in some Scientific and Professional associations.

Some activities of the group have received regional and international recognition. Prof. Dissanayake and I have been involved actively in the activities of Asian Society for Solid State Ionics since its inception in 1986 and have organized the 5th Asian Conference on Solid State Ionics (ACSSI-5) successfully in Sri Lanka in1996. Now the group has been again entrusted with the task of organizing 10th Asian Conference on Solid State Ionics (ACSSI-10) in Sri Lanka in 2006. The group is also planning to make Peradeniya as a regional centre for promoting research in technologically important materials in the region, with the support of IPPS in the near future. Plans are underway to train some of Cambodian Physicists as a pilot programme under the proposed centre.

All the above achievements during the period of nearly 20 years have been possible due to several reasons: the closely monitored continued support given by the IPPS, the correct choice of research projects, the proper guidance and support offered by the host Scientists, mainly from Sweden and Denmark, and the good team work by the members of the group. Apart form sustaining high-level research programmes on technologically important novel materials, the group has also catalysed the research-work in other universities in Sri Lanka and in the region. This has been done through training young researchers, organizing seminars, workshops, conferences and by publishing joint research papers.

5. CONCLUDING REMARKS

The Department of Physics at the University of Peradeniya provides a successful example for the development of research activities in Physics in a Developing Country. This programme also has demonstrated the effectiveness of the sandwich Ph.D. programmes, not only in providing a combination of local and foreign postgraduate training to students but also in reducing the brain drain of trained Physicists.

Technologically important new materials is a good area for research in developing countries, as the input required is minimal and (once established) the research can be sustained with local resources. This line of research, while helping to build the knowledge-base of the country, may be useful in developing material and knowledge based industries. The dedication of the researchers, team work and correct choice of projects are essential for the success of the research activities. However, to maintain the standard and to keep the research up-to-date and to give opportunities for the students to work in advanced laboratories, the project must be carried out, whenever possible, in collaboration with well-established institutions.

The authorities in developing countries should provide encouragement and incentives for the researchers to initiate and sustain Physics-related research activities. The donor agencies, following the practice of the IPPS, should play an active role in promoting research-activities in developing countries, rather than merely providing funds. For the success of the research activities, the agencies should interact with the researchers, closely monitor the progress and provide assistance in identifying collaborators from the developed countries with a commitment to support the deserving projects on a long-term basis.

ACKNOWLEDGEMENTS

The financial support provided by the IPPS, Sweden, European Union, National Science Foundation, Sri Lanka, University of Peradeniya, PGIS, Sri Lanka, and the guidance and support provided by all our collaborators for developing the Solid- State Physics research at Peradeniya are greatly acknowledged. Appreciation is also extended to COMSATS for providing financial support towards my participation in the International Seminar on Physics in Developing Countries: Past, Present and Future.

REFERENCES

1. 'Strategic Approaches to Science and Technology Development (2004)', World Bank.
2. 'Starting Physics Research from Scratch', M.A.K.L. Dissanayake, Proceedings of the International Conference on 'Physics and Physicists for Development', University of Twente, The Netherlands, September 10-11, 1990, p 62.
3. 'Why Sri Lanka is lagging in Science and Technology?' Kingsley A.de. Alwis, Proceedings of the workshop on 'Impediments to Science and Technology Development in Sri Lanka', National Academy of Sciences of Sri Lanka, October 30, 2004, p13.
4. IPPS SRI: 02, Project Catalogue 2002, International Programme in the Physical Sciences, Uppsala University, Sweden.

COMBINING COLONIAL AND AMERICAN EDUCATIONAL SYSTEMS TO IMPROVE THE STANDARD OF PHYSICS IN THIRD-WORLD COUNTRIES

Chandima Gomes
Department of Physics, University of Colombo
Colombo 03, Sri Lanka

ABSTRACT

The physics teaching environment of a traditional university in Sri Lanka is analysed, taking into account the link of the educational system in the university to the colonial past of the country. The teaching environment of a newly formed American-based university in Colombo is also analysed and various characteristics of the two systems are compared. The effectiveness of the colonial system and the American system in the transferring of innovative skills and smart thinking in Physics to the students is investigated by applying feedback techniques to two similar samples of students in the two systems.

Three voluntary tasks were given to the two groups at different stages of the course. The outcome reveals that the American model is more effective in developing the innovative thinking and effective knowledge-transfer. Based on the outcome of the analysis, an appropriate method of combining the colonial and American systems to improve the quality of Physics in a third world country is proposed.

INTRODUCTION

Many countries in Asia and Africa were under the rule of either British or French Empires for over 100 years before they were offered liberty in the mid nineteens. Therefore in many such countries the educational systems were formulated according to the colonial concepts that prevailed in the early 20th Century. While the colonial masters have gone through many educational reforms to adopt new teaching and learning methodologies during the last few decades, the countries which were under these regimes have been self-locked in conceptual dungeons built up in the beginning of the last century. Although the description is applicable to other spheres as well, in this paper the contents are confined only to Physics.

Several countries with such colonial past broke away from their self imposed frames during the last quarter of the 20th century by adopting educational systems similar to that in USA. Thailand, Korea and Singapore are examples for such countries. They

have reached considerably high levels of performance in physics education by the advent of the 21st century. Therefore, in this paper our objective is to investigate the pros and cons of colonial educational system and to propose a method to transfrom such a system into an American educational system with the least hazardous effects on the student-teacher communities.

To achieve the above discussed tasks, we selected two educational institutions in Colombo, namely the University of Colombo and the American National College (ANC) which is an extended campus of both Patten University and Northwood University in USA. The University of Colombo has a history of almost 100 years (the name has been changed several times). It was established during the time that Sri Lanka was under the British Government; thus the educational system, even at present has many resemblances to the colonial era. In contrast, the ANC was formed in the year 2002. The institution offers the courses in various streams for the first 6 semesters for a student seeking an American Degree. After this period, the students are transferred to an American University, depending on the results obtained. In both institutions, the selected samples comprised freshmen who are taken immediately after their high school career. Hence, the chances of them being completely absorbed into the respective systems are minimal.

THE EDUCATIONAL ENVIRONMENT

At the University of Colombo, the syllabi of subjects at a department is formulated after going through a long reviewing procedure by a panel of experts. Thus, the final syllabi are very good in standard. Once the syllabi are formulated and approved by the faculty board, they are in operation for a period of about 10 - 12 years. The individual lecturers that conduct the courses have very small margin to deviate from the core syllabus. The examinations are held, usually as a single written paper at the end of the semester or academic year. The practical component is conducted as a separate subject unit. Despite some reforms done recently, the physics syllabi still contain a vast collection of information on the concepts of elementary physics. Such vast syllabi reflect the lack of interactive and demonstrative teaching in the system. In particular, due to the long syllabus that has to be covered within a limited period, the teacher concentrates more on achieving time-goals rather than conducting classes in an interactive environment. A large course-content of elementary principles given in the notebook-format, in place of a short syllabus with demonstration kits and interactive modes, has proven to be a poor replacement, as it may direct the students to regard physics as a knowledge to be memorised and recalled at the examination (Zollman, 1990)

Most of the physics lecture-halls of traditional universities are characterised by a large closed table with a height of about 1.2m that separate the last student line and the lecturer's teaching position. Originally, this table has been designed for conducting practical demonstrations; however, now such performances are hardly practised and the table has become a large psychological barrier between the student and the teacher.

Basically, in the colonial frame within which physics is taught, the subject knowledge and scientific imaginations of the student are developed around the personality of the teacher, as has been revealed by the surveys done with a large sample of physics students. This heavenly figure of the teacher is a direct result of the master-servant perception of the colonial era and boosted by the father-centred social system in South Asia. Such conceptual impressions develop negative approaches among the students, both in subject-exploration skills and their scientific personality.

At American National College, the responsibility of formation and alteration of the syllabi is vested on the lecturer who conducts the courses. Thus he has a vast scope to design the course in a way that it suits his teaching skills and student group. The evaluation procedure has been divided into six segments and is conducted throughout the semester. The evaluation consists of two written papers on module quizzes, mid-semester and semester-end written papers, and a group presentation. A continuously evaluated practical component is also integrated into the course. The students are individually approached by the lecturer after each examination and advised regarding their lapses. The lecture rooms are also designed to have more physical approach between the students and the teacher. The students are in a semi-circle around the teacher who conducts lectures at the same floor-level. Thus, psychological barriers between the student and the teacher are minimised. In an American-system based educational environment, Physics is treated not as a collection of information that should be stored in the student's memory and recalled at the examination, but as a way of observing, collecting data, critically thinking, building models and comparing with nature. Thus, teaching physics is a challenging task, rather than a routine work of imparting the information the teacher has gathered. When this fact is understood the course implementation as well as the teaching techniques can be reorganised in such a way that the students are premeditatedly attracted towards the physics streams (Nappi, 1990; Konuma, 1992)

METHODOLOGY AND OUTCOME

The objectives of the following investigation were to understand the efficiency of imparting physics knowledge and skills to the students and to determine the development of innovative thinking of the students with respect to physics. A sample of students that follow a course on general physics, at the beginning year at the university of Colombo, was selected in the year 2001. The regular attendance to the class was around 80. They have passed the General Certificate of Education (Advanced Level) examination with good grading. At ANC, a group of students that follow general physics course has been selected in the year 2003; the regular attendance was about 25 students. They are of somewhat lower educational standard compared to that of the sample at the University of Colombo. The course syllabi at the two places were similar; however, the depth of sections of the syllabus at ANC was less. The teacher in both cases was the same.

Results: The students were given a spot-test (written) on the subject, 3 weeks after the

commencement of the course. At ANC the test was treated as a part of their evaluation process (quizzes-1). According to the results at ANC, the marks were fitted into a Gaussian distribution with mode value around 60% of the full marks. At the University of Colombo, about 10% of the students got almost full marks (above 95%), while about 70% of the students got marks less than 40% of the full marks. However, at the year-end examination, the same group obtained marks that could be fitted into a Gaussian distribution with mode value at 62% of the full marks.

In the second test, conducted during the 6^{th} week, the students were asked 10 oral questions from general concepts of physics. The questions were given to the entire class, one after the other, and the students are asked to give answers on a totally voluntary basis. At the University of Colombo, the students responded in only 4 questions (one response for each question) and all four responses were correct. At ANC, 23 responses were obtained for the 10 question, out of which 6 were correct.

In the third case, at the end of the course, the students were asked to prepare a short document explaining a solution to the energy-crisis, considering that fossil-fuel will be completely exhausted within the following year. The students were told that the task is voluntary and a no-response is not going to affect their grading or any other requirement. At the University of Colombo, none of the students responded to this request, while at ANC 19 responses were received. Subsequent personal communication revealed that the students of the University of Colombo were not interested in the task, as they had to spend their time on preparatory work for the year-end examination. The students at ANC had only their semester-end examination during this period, which carries only 30% of their final grading.

DISCUSSION OF RESULTS

The outcomes of the three tests conducted show that the knowledge-transfer, skill-development and the enhancement of innovative thinking is better in the American Educational system, despite a well revised, high-quality syllabi applied in the traditional university system. The major reasons for this drawback in colonial university system may be the teaching environment, student-teacher relationship and the teaching methodologies that give priority to time-constraints, rather than interactive transfer of knowledge.

The development of conceptual understanding is an important component of learning physics. A goal is to have students describe and explain physics in words and put their knowledge into practise in a teacher-guided environment, in place of just solving numerical problems and recalling information. The teacher should also assist the students' general intellectual development, as well as improve their knowledge of physics. In the American system, these goals are generally reached through teacher-guided activities, rather than teacher-centred learning as being practised in the colonial system (Van Heuvelen, 1991). While, some modern educational technologists recommend student-centred learning as a better replacement to teacher-centred

learning, this may cause very undesired outcomes in countries having a long- standing colonial system. In many South Asian countries, the youngsters up to maturity are mostly dependent on the family, so that they are brought up in an environment in which they built up their character and personality around a father-figure. Similarly, in the educational environment, the students develop knowledge-base and thinking on the image of the teacher. Hence, destroying this conceptual frame and suddenly adopting a student-centred learning environment may cause very undesired sequences, such as mental strain, frustration and personality retardation among the students. Therefore, a colonial physics-education system should be carefully and gradually transform into a teacher-guided system, taking social and ethical barriers of the country also into account

RECOMMENDATIONS

i. The universities in the third-world countries should model the physics-education system in wuch a way as, to encourage the development of innovative scientific imaginations within the students.
ii. In planning the education, system the social and cultural background should be taken into account. A teacher-guided, student-friendly atmosphere should be developed in the classroom.
iii. The evaluation methodology should be split into several parts

ACKNOWLEDGEMENT

The author would like to thank the head, Department of Physics, University of Colombo, and the Dean, American National College for providing the facilities at their respective institutions to conduct this research.

REFERENCES

- Konuma M., *Japan and the educational challenges in the 1990s*, AAPPS Bulletin, Vol. 2, No. 4, 1992
- Nappi C., *On Mathematics and Science education in the US and Europe*, Physics Today, 77-79, May 1990.
- Van Heuvelen A., *Learning to think like a physicist: A review of re-search-based instructional strategies*, Am. J. Phys. 59, 891-897, 1991
- Zollman D., *Learning cycles for a large enrollment class*, The Physics Teacher 28, 20-25, 1990

advancements.

Unfortunately, not much of the comforts of such advancements have been accessible to a huge population in under-developed and developing countries. Add to it the high population growth-rate in these countries, and the result is the widespread deprivation and disenchantment. This has resulted in a logical tendency of migration from such countries to the developed ones. As such, a strategically important issue crops up that warrants support in education and ensure equitable share in the fruits of modern technologies. Part of this responsibility is to be shared by the physical sciences; physics included.

PROPOSED SOLUTION

One possible solution to this problem could be afforded by a suitable choice of effective system of education in physics. In this respect, the study of the educational system of the Soviet Union might be useful, since physics was developed these at the highest level. In this regard, one may observe that this system was established after the end of the Second World War. Some essential elements of this system are listed below:

1. Education was free of cost at all levels, from school to university
2. Network of schools with 4-, 7- and 10-years of education was established in all the villages, with the same educational standards
3. The children used to spend the first four years in one school, then go to another school for education up to Class 7, and on to another school for education up to Class 10
4. The trainings, as a rule, were conducted in the national languages (more than 100 nationalities!)
5. The Main books were published in all the national languages
6. One uniform system of alphabets – Cyrillic - was used
7. All children were trained both in national and Russian languages
8. In some Republics (Georgia, Armenia, Baltic Republics and West Ukraine), apart from Cyrillic, education was provided in the national language, using their national alphabets
9. Education was made compulsory for all the children from age seven
10. It was considered a crime if a child of that age was not given education, for which the local authorities and the director of schools were to be penalized
11. A sufficient number of state boarding-schools for orphans were built, where they were provided books, clothes, four meals a day, accommodation, and were engaged in study and sports

---

12. The teacher was held in high respect by the people and the local authorities
    - In remote villages, he was considered as the carrier of knowledge and culture
13. High salaries were offered to the teachers
    - Salaries paid to the teachers exceeded the salary of the head of region or city (up to 1960), while the salary of a professor was up to two times the salary of

the leader of a republic (up to 1985)

14. Training for teachers was conducted in pedagogical universities and colleges
    - In Tajikistan, the Pedagogical Institutes were opened in Dushanbe (capital of the Republic), Khujand (north of the Republic), Kulob (south of the Republic) and Khorog (east of the Republic)
15. There were two types of trainings in these institutes:
    - Formal (morning and evening programs); and
    - Distance learning
    - The students (teachers of the primary schools) from far off places would complete 2-3 assignments/tests in each subject, each year
    - During the school-holidays (June-August), they were to attend lectures in a college/university for two months and were then allowed to take the examination
16. Multiple national and technical universities were established all over the country
    - For example, the Tajik State National University was established in 1948
17. All the educational labs were equipped with modern equipments
18. University education was of 5-year duration
19. In all universities, courses of physics, chemistry, mathematics and other disciplines were conducted under uniform program and, whenever possible, the medium of instruction was a national language
    - It allowed the students to master the contents of physical and chemical laws, and also mathematical formulas in a better manner

19. Students were required to do research work in order to get the degree
    - Often research was conducted on such a high level that it was published in international journals
20. There were three types of stipends available to students:
    - Ordinary: All the students passing the examination in good category were entitled to this (e.g., $45 per month in 1965);
    - Higher: Students passing 75% of the examinations in excellent category were entitled to this (e.g., $60 per month in 1965);
    - Lenin: Students passing all the examinations in excellent category with some active participation in the community work were entitled to this (e.g.,$110 per month in 1965)
21. Large research centers were created where only physics, chemistry, mathematics and biology were developed
22. Talented young scientists were appointed as directors of these centers. The number of such centers increased with time
    - An example of such centers of science was the Novosibirsk Centre of Science, on the basis of which centers of science were setup in the Western and Eastern Siberia, Ural and also in the Far East
23. National academies of sciences were established in all the allied and autonomous republics
    - The main research directions in these academies were the investigation of natural resources and development of fundamental sciences
    - Eminent scientists in physics, mathematics, chemistry, and biology were

invited from the major scientific centers of the Soviet Union to these academies
  - For example, in 1951 the Tajik Branch of Academy of Sciences was transformed into the Academy of Sciences, Republic of Tajikistan
- Hereinafter, the number of institutes in the Republic of Tajikistan reached up to 22
- With this, the number of scientists at the academic institutes also increased:
  - For example the S. U. Umarov Physico-Technical Institute, which had 30 scientists in 1964, had 300 scientists working in 10 labs in 1985
- In these labs, equipped with modern instruments, experimental researches were conducted on the following themes:
  i) Raman scattering of single crystals;
  ii) Acoustic properties of some single-crystals near temperature of phase transitions;
  iii) Relaxation properties of liquids and electrolytes;
  iv) Growth of new opto-acoustic crystals and study of their structures and properties;
  v) Physical properties of organic and inorganic semiconductors for a wide range of temperature- variations;
  vi) Study of the Features of the destruction of many polymeric materials through Mass-spectrometry;
  vii) Thermo-chemical processes in the lasers radiation field;
  Viii)A series of experimental researches was conducted on the spectral properties of different filaments, including that of cotton;
  ix) In 1978, for the first time in Central Asia (and also Islamic World) the liquid Helium at T=4K was obtained and spectral polarization and electro-physical properties of single crystals and some high- temperature superconductors at liquid Helium temperatures were studied;
  (x) The molecular theory of structural relaxation in simple fluids was presented; and
  xi) The theory of the double-scattering of light near the critical point was constructed
- A research lab (ca. 1000m^2 area) was installed at an altitude of 5,000m amsl in the eastern Pamir, with the cooperation of other republics and Poland, where research was conducted on the investigation of the energy-spectrum of the cosmic rays and physics of high energy
  - As a result, new discoveries were reported about the interaction of cosmic rays with the atmosphere and Earth's magnetic field on this installation
- During existence of this institute, its scientists published more than 20 books and about 2,000 research papers in international journals

24. Multiple specialized physico-mathematical schools were opened all over the country
- Students for these schools were selected at All-Union Olympiads and regional competitions held in mathematics and physics for schoolchildren
- Many graduates of such schools became prominent scientists in these areas

and made significant contributions, in particular, to modern physics

- Regular summer physico-mathematical and chemical schools were held for the young generation
- As a rule, these schools were set up in the comfortable places at the hilly stations, and headed by famous scientists from the Academy of Sciences
  - For example, in Tajikistan, the President of the Academy of Sciences, a well known scientist and philosopher, M.S. Asimi, was head of such a school
- The teachers selected for these schools were scientists from the Physical-Technical Institute, Institute of Mathematics and Institute of Chemistry, Tajik Academy of Sciences (TAS)
- During training in these schools, the students from different regions and institutes had the opportunity to meet famous scientists
- A good relationship would thus he established between students and scientists and also among students of different institutes in this academic village
- At the concluding session, olympiads were conducted among senior students (Class 10)
- The winners would get a certificate for admission in various universities of USSR (without an entry test)
- Students of lower classes would get a scholarship to continue their studies in the physics-mathematics school of Novosibirsk city

25. The so called "Small Academies" were organized to select gifted and talented schoolchildren. Young academicians were elected to the academy
26. The system of postgraduate institutes (called Asperantora) was meant for PhD students:
    - Admission to these institutes was based on competition
    - Post-graduate students were completely relieved of their other duties and were occupied in research work
    - The entire needed lab. equipments were made available to them
    - As per this education system, they were taught English and the fundamentals of philosophy
    - They were provided scholarships (more than $100 per month) and free accommodation
    - If a student's level was not up to standard, he would spent two years in any centre of science in the USSR, before coming back to the postgraduate institute
    - If one failed to complete his PhD research in 3 years, he would get dropped and no re-admission was allowed
    - For the successful completion of PhD, the student should have a minimum of 3 publications in international journals and would submit a thesis for defence
27. For producing high caliber scientists, there existed a system of Doctorantora [doctor degree] of 6 months to 2 years duration
    - Only those scientists could go for Doctorantora who had a certain number of publications in international journals
    - They were also required to take leave from teaching and other duties

- They had the opportunity to go to the centers of sciences and complete their research by utilizing all the available facilities, including information bank of libraries
- For the defence of doctoral thesis (second scientific degree), there existed a committee relating to that field of research in these centers
- Only those scholars were recommended for defence who has some new scientific discovery or some sort of invention
- The average time required for the doctoral degree was 10 years
- In exclusive cases (news about a huge discovery, either theoretical or experimental, resulting at PhD level), the doctoral degree could be conferred earlier.
- It may also be known that the second scientific degree existed only in the USSR; not in the western countries

CONCLUSION

Thus, it can be concluded that the USSR had an effective system for education and research as well as to produce scientists of high calibre. To implement that system of education fully elsewhere, is obviously not easy, especially in the developing countries. However, we believe that some elements of this system can be used to develop physical sciences in several developing countries and thus implement modern technologies for their economic growth and to raise the standard of education and, with that, the standard of living of the population in these countries.