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INTERNAL REPORT

International Atomic Energy Agency

and

United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

P H Y S I C S   A N D   D E V E L O P M E N T

No.4

MIRAMARE - TRIESTE

November 1984

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PHYSICS AND DEVELOPMENT

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SCIENCE TRANSFER FOR DEVELOPMENT

Abdus Salam

"Government support of basic research is a Federal trust ... basic research (is) an essential instrument in the nation's long-term welfare because its benefits are so broadly distributed. Quite simply basic research is a vital underpinning for our national well being." - George A. Keyworth II, U.S. Presidential Science Adviser, testifying before the House Committee on Science and Technology, 1984.

1. The Neglect of Basic Sciences in Developing Countries

Let me say at the outset that my credentials for writing on this subject are those of a humble research physicist from a developing country who has had the privilege of directing a United Nations run International Centre for Theoretical Physics (ICTP) at Trieste. Since its inception in 1964, ICTP has welcomed of the order of 22,000 visits of experimental and theoretical research physicists; 11,000 of these working in developing country Universities and Research Institutes.

Based on this experience, gained over the past twenty years, the thesis I wish to present is this: barring a few of its countries - Argentina, Brazil, China and India - the third world, despite its recent realization that science

and technology are the sustenance, and its major hope for economic betterment, has taken to science - as contrasted over to technology - as only a marginal activity. This is also true of the aid-giving agencies of the richer countries, of the agencies of the United Nations and also unfortunately, of the scientific communities of the developed countries which might naturally have been expected to be the third world scientists' foremost allies. My purpose in this article is to reflect on the position of Sciences in the developing countries, and to highlight, in particular, the role of the United Nations and other Agencies in ameliorating the situation.

Why am I insistent that science in developing countries has been treated as a marginal activity? Two reasons:

First: policy makers, prestigious commissions (like the Brandt Commission), as well as aid-givers, speak uniformly of problems of technology transfer to the developing countries as if that is all that is involved. It is hard to believe but true that the word "science" does not figure in the Brandt Commission report. Very few within the developing world appear to stress that for <u>long term effectiveness, technology transfers must always be accompanied by science transfers</u>; that the science of today is the technology

tomorrow and that when we speak of science it must be broad based [(1)] in order to be effective for applications. I would even go so far as to say;

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(1) Steven Dedijir has given an example of broad-based science necessary for applications, which I quote in his words:

"RAW MATERIAL RESEARCH

<u>Analytic Chemistry</u>	<u>Organic Chemistry</u>	<u>Ultrastructure</u>
I. <u>Detection and elimination of harmful factors</u>	II. <u>Effect of technological process on nutrients</u>	III. <u>Nutritional and sensory evaluation of food formulas</u>
Clinical Chemistry Alimentary sciences Toxicology Nutrition and Metabolism Physiology	Physics Ultrastructure Alimentary sciences Organic Technology	Technological Mathematics Sensorial metrology Experimental medicine Physiology Nutrition and metabolism

The above table translated from a 1981 Nestle pamphlet illustrates the <u>strategic advantage</u> the industrialized countries have in all <u>technology transfers</u> over the other countries. The table shows all the basic and applied sciences Nestle uses to develop, from the Soya bean plant, a series of products, processes and production units. The brochure then shows how these products, processes, factories are "transferred", among others, to the South. The scientific base - the know-why, know-how, know-who of science - is not transferred. It remains "at home" as a foundation for newer, better industrial outputs.

The scientific base of all products and processes, is becoming stronger. The more science a new product or process has, the more it is liable to be competitive. Most Third World countries have hardly any creative science. <u>Ninety per cent</u> of world research potential is concentrated in about 35 countries with about 25% of world population. Hence the imperative necessity for a Third World country to find the most effective policy to bring about rapidly a <u>macro science transfer</u> on which to base its development. Without such a science transfer a Third World country will continue to be technologically, and hence economically and politically, <u>one-sidedly dependent</u>, more simply said, exploited in its international exchanges".

if one was being machiavellian, one might discern sinister motives among those who try to sell to us the idea of technology transfer without science transfer. There is nothing which has hurt us in the third world more than the slogan in the richer countries of Relevant Science. Regretfully this slogan was parrotted in our countries unthinkingly to justify stifling the growth of all science.

<u>Second</u>: science transfer is effected by and to communities of scientists. Such communities (in developing countries) need building up to a critical size in their human resources and infrastructure. This building up calls for wise science policies, with long-term commitment, generous patronage, self-governance and free international contacts. Further, in our countries, the high-level scientist must be allowed to play a role in nation-building as an equal partner to the professional planner, the economist and the technologist. Few developing countries have promulgated such policies; few aid agencies have taken it as their mandate to encourage and help with the building up of the scientific infrastructure.

2. <u>Why Science Transfer?</u>

What is the infrastructure of sciences I am speaking about and why? First and foremost, we need scientific literacy and science teaching - at all levels - and particularly at the higher levels, (at least) for engineers and technologists. This calls for inspiring teachers, and no one can be an inspiring teacher of science, unless he has experienced and created, at least some modicum of living science, during some part of his career. This calls for well-equipped teaching laboratories and (in the present era of

fast moving science), the provision of the newest journals and books. This is the minimum of scientific infrastructure any country needs.

Next, should come demands on their own scientific communities - consisting of their own nationals - from the developing country government agencies and their nascent industries, for discriminatory advice on which technologies would be relevant and worth acquiring.

Still next, for a minority of the developing countries, there is the need for basic scientists to help their applied colleagues' research work. For any society, the problems of its agriculture, of its local pests and diseases, of its local materials base, must be solved locally. One needs an underpinning from a first-class base in basic sciences to carry applied research in these areas through. The craft of applied science, in a developing country, is much harder than the craft of basic science, simply because one does not have available next door, or at the other end of the telephone line, men who can tell you what one needs to know of the basics, relevant to one's applied work[*)].

[*)] Fang Yi, the Chinese Minister of Science and Technology has given another reason for support of basic sciences. Noting that major technological advances will become more and more dependent on breakthroughs in basic research he has made the point that "'some foreign countries' will be less willing to publicize their basic research in the open literature. China should therefore pay ever more attention to such fields of basic research". "Nature", Vol. 307, 2 February 1984.

And finally, at the advanced stages[**)] of a country's development, is the need for basic scientific research for the riches it might unexpectedly yield for technology. Many examples of this come to one's mind.

Consider some of the breakthroughs in my own field - the field of unification of fundamental forces of nature. In this context, Faraday's unification of electricity and magnetism, accomplished in the last century, is certainly one of the most striking examples. When Faraday was carrying out his experiments - showing that while a <u>stationary</u> electric charge produces an electric force on another charge in its vicinity, a <u>moving</u> electric charge produces a magnetic force - no one could have imagined that this simple discovery in a laboratory in a dilettante part of Piccadilly in London would lead to the entire corpus of electrical generation technology.

Just to emphasise how relatively useless Faraday's work was thought to be by his contemporaries, consider the assessment by one of them, Charles Burney, of the uses of electricity versus music. "Electricity is universally allowed to be a very entertaining and surprising phenomenon, but

[**)] I have assumed throughout this article that no one in authority in developing countries, is in the slightest bit interested in the advancement of knowledge for its own sake - at least not by third world nationals working in the third world!

it has frequently been lamented that it has never yet, with much certainty, been applied to any very useful purpose. ... (while) it is easy to point out the humane and important purposes to which music has been applied. ... Many an orphan is cherished by its influence, and the pangs of child-birth are softened and rendered less dangerous ...".

The story of the unification of electricity with magnetism continues with Maxwell, who immediately followed Faraday. From purely theoretical considerations, Maxwell suggested that an accelerating electric charge wouldproduce electromagnetic radiation. A few years after Maxwell's death in 1879, Hertz in Germany verified Maxwell's predictions and found that the spectrum of Maxwell's predicted radiation consisted not only of light waves, but also of waves of longer wave length - radio waves - as well as waves of shorter wave length - X-rays. Thus, from a simple theoretical calculation made by an obscure professor flowed the marvels of radio, television and the modern communication systems, as well as the ability to see through a human body with X-rays.

To see how the climate has changed in developed countries since Faraday's time, when a hundred years after Maxwell, in the 1960s, my colleagues at Harvard, Glashow and Weinberg, and I independently took the next step of postulating a unification of two further forces of nature - of electromagnetism with the weak nuclear force of radioactivity - even the London "Economist" took note and counselled perceptive businessmen not to ignore the likely economic consequences of this new development.

Last year, in January, the great joint European Centre for Nuclear Research (CERN) at Geneva provided direct confirmation of our theory. It did so with technical brilliance of the highest order, at a cost of around $50million. I am not suggesting that the developing countries should create accelerator laboratories like Cern. However, even if the London "Economist" may have been optimistic in its forecast of direct economic benefits of the new unification of forces, there is no question that these accelerator laboratories are founts of the highest technology in micro-electronics, in material sciences, in superconductor as well as vacuum technology. I rejoice that the Fermi Lab at Chicago has decided to set up a special Institute linked to the Laboratory, to make this area of science and related technology available to Latin American physicists. And the Cern laboratory has made available to us - the Trieste Centre - the services of some members of their microprocessor team who have already conducted two six-week colleges on microprocessor physics and technology at Trieste at the highest level, for 250 of the developing world's physicists. During June 1984, this team is holding a four week microprocessor college in Sri Lanka for 62 physicists from South East Asia; to be followed during 1985, 1986, 1987 and 1988 by four week colleges in China, Colombia, Kenya and Morocco on the same subject.

To summarise then, technology in modern conditions cannot flourish without science flourishing at the same time. This was emphasised recently to me by a Turkish physicist from the University of Samsun who recalled that Sultan Selim III did introduce studies of algebra, trigonometry, mechanics, ballistics and metallurgy in Turkey already as long ago as 1799, creating special schools for

these disciplines with French and Swedish teachers. His purpose was to modernize his army and rival European advances in gun founding. Since there was no corresponding emphasis on research in these subjects, Turkey did not succeed. In the long run, in the conditions of today, technology, unsupported by science, simply will not take or flourish.

3. The Situation of Sciences in the Third World

Let us turn to the situation of science, and scientific research in the third world, barring the few countries (Argentina, Brazil, China and India) I have mentioned before. I can illustrate the situation from the example of my own country. In 1951 when I returned to teach in Pakistan after working at Cambridge and Princeton in high energy physics, in a country then of 90 millions, I could call on just one physicist who had ever worked on a like subject. The most recent issues of the "Physical Review" available were dated before the Second World War of 1939. There were no grants whatsoever for attending symposia or conferences; the only time I did attend a conference in the United Kingdom I spent a year's personal savings.

After 30 years, the situation in Pakistan has improved. For a population of around 80 million now, there are some 46 research physicists, experimentalists and theoreticians in Pakistan's 19 Universities. (On the US norms these numbers for this population base might have been one hundred-fold larger - i.e. five thousand). These physicists still face the same problems regarding journals, publication dues and attendances at conferences; Pakistan is still not a member of the International Union of Pure and Applied Physics, since our science administrators do not think we can afford $1.500 of dues; our physicists are still told that all basic science - even the segments

necessary for 'applicable' physics - is a frightful luxury for a poor country. However, compared to Pakistan - and a privilged group of some 30 countries which I shall presently mention - the situation in the remaining 60 odd other developing countries is as stark as it was in Pakistan of 1951. First and foremost is the problem of numbers - of a critical size. The total number of research trained physicists in many of these countries can be counted on the fingers of one hand - the choice of sub-disciplines in which they may have received training has been conditioned more by chance than design. They make up no communities.

The creation at Trieste of the International Centre for Theoretical Physics in the 1960s came about when some of us from the developing countries urged agencies of the United Nations, and in particular the International Atomic Energy Agency (IAEA) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), to assist in ameliorating this situation regarding theoretical physics research. We met with incomprehension even from some of the developed countries where physics in fact flourishes. One developed country delegate to the IAEA went so far as to say: "Theoretical physics is the Rolls Royce of sciences - the developing countries need only bullock carts". To him a community of even as few as fifty physicists, all told, trained then at a high level, for a country like Pakistan with a population then approaching 120 millions, was simply 50 men wasted. Even leaving aside any involvement in research - that these were the men responsible for all norms and all standards in the entire spectrum of Pakistan's education in physics and mathematics was irrelevant. He himself was an economist, who had wandered into a scientific organization like the IAEA. He could fully understand that we needed more high-level economists,

but a few more re...rch trained physicists and mathematicians of quality - that was wasteful luxury.

In 1964, four years after the proposal was first mooted and after intense lobbying, the IAEA did agree to create a physics institute. However, we were voted all of a sum of $55,000 to create an international centre of research. Fortunately, the Government of Italy came through with a generous annual grant of one third of a million dollars and the Centre was set up in Trieste. The international physics community had all along supported us; the Centre's first Scientific Council meeting was attended by J.R. Oppenheimer, Aage Bohr, Victor Weisskopf and Sandoval Vallarta. Oppenheimer drew up the Centre's statutes.

The Centre started operating in 1964. UNESCO joined as equal partner with IAEA in 1970. The Centre has flourished since then, with the support of even those who doubted its validity at first. The bulk of its funds - now amounting to 4.5 million dollars - come from Italy, IAEA and UNESCO. Smaller ad-hoc grants have come from time to time from the United Nations Development Programme (UNDP), the United Nations Financing System for Science and Technology for Development, the United Nations University, the OPEC Fund, the US Department of Energy, the Ford Foundation, the Intergovernmental Bureau for Informatics (IBI), Canada, Kuwait, Libya, Qatar, Sweden, Germany, Sri Lanka, Netherlands, Japan and Denmark Over the 20 years that the Centre has existed now, it has shifted from emphasis on pure physics towards basic disciplines on the interface of pure and applied physics disciplines like physics of materials and microprocessors, physics of energy physics of fusion, physics of reactors, physics of solar and other non conventional energy, geophysics, biophysics, neurophysics, laser physics, physics of oceans and deserts, and systems analysis - this, in addition to the staples of high energy physics,

quantum gravity, cosmology, atomic and nuclear physics and mathematics. Such a shift to the interface of pure and basic applied physics was made simply because there was not and still is not, any other international institute responsive to the scientific hunger of developing country physicists.

One of the most important examples today of this is in the field of physics and energy. Provision of energy is at present one of the major concerns of mankind. In country after country, either new departments of energy have been created or the Atomic Energy Commissions transformed to become comprehensive departments of energy. Notwithstanding all the United Nations Conferences, to my knowledge there still does not exist any International Centre for Energy Research and Training on the scientific side, for meaningful training and research for developing countries' scientists. Without a good base in solid state and material sciences, there is no hope whatsoever of making good in this area. An optical convertor must make use of as little material as possible; how little is determined by the penetration depth of the solar light and drift length of the excited state on which the conversion is based. For an amorphous material this depends on the density of defects and an understanding of these. Efficient and cost-effective photo-voltaics thus depend on physics of solid state materials and not on a technologist's tinkering. To fill part of the need, the Trieste Centre has felt that it should develop and concern itself with high-level physics of energy-related materials, and in particular, with physics of absorbing and emitting surfaces So far our Colleges in this field have had participation of around 1000 physicists

To quote the London "Economist" again; in its issue of 27 September 1980, it had this to say about this area: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology roof-top radiators. A breakthrough (will) come from applying quantum physics, biochemistry or other sciences of the 20th century. Today's technology-based industries all depend on new science".

During 1983, 2400 physicists came to work at the Trieste Centre - 1400 of them from 90 developing countries. Those from developing countries spend on the average, of the order of two months or more at the Centre, participating in its research workshops and extended research colleges. Since 1981, we have held four of these colleges in developing countries - Ghana, Bangladesh, Columbia and now, in Sri Lanka; these were 4 - 8 week research colleges on solid state physics, monsoon dynamics, solar physics and microprocessors. We have pioneered an associateship scheme which guarantees that top physicists in developing countries can come to the Centre, at times of their choosing, for a period ranging between six weeks to three months, three times in six years, to work in a stimulating environment of their peers, to charge their batteries and then to return to their teaching and research positions. We do not pay salaries - only travel and stay. There are 200 such associates at present. We have a network of 102 institutes of physics in 41 developing countries federated with us with cost sharing arrangements. Through a Book Bank scheme, we have distributed, from individual donations, a total of 2,565 books and 8,542 copies of recent journals to 132 institutions in 66 countries, and we are beginning a scheme to collect and distribute unused surplus equipment

donated by developed country laboratories. With an Italian Government grant of the order of one third of a million dollars annually, we have placed 75 experimental physicists for 6-9 month research in Italian University and industrial laboratories since 1982. In its humble way, the Centre has enhanced the subject of Physics in general, and physics communities in developing countries in particular.

4. Stages and Growth of Sciences in the Third World

Based on the experience gained in Physics, we could divide the developing countries (other than Argentina, Brazil, China and India) into three categories. The first category would consist of 9 countries - Bangladesh, Korea, Malaysia, Pakistan, Singapore and Turkey in Asia, plus Egypt in Africa and Mexico and Venezuela in Latin America. These countries have a population of physicists, currently approaching criticality, as well as a few centres of high quality for physics where teams of scientists can perform independent research. By and large, these centres are capable of awarding Ph.D. degrees for physics within the countries themselves.

In the second category, there would be some 19 countries which consist of Iran, Iraq, Jordan, and Lebanon in the Middle East; Indonesia, Philippines, Sri Lanka, Thailand and Vietnam in South East Asia; Algeria, Ghana, Kenya, Morocco, Nigeria, Sudan, Tanzania in Africa; and Chile, Colombia and Peru in Latin America. These countries have a modest population of physicists though at any given university the numbers working are rather small. There are no research groups as such, though in some cases individuals are highly active. As a rule, Ph.D. degrees are not awarded within the countries concerned. I

mention these two categories, because with organized help from the rich world's scientific communities, these countries may take off in a short span of time.

The remaining 60 countries are below the "poverty line" - some exceptionally bright individuals, whom we elect as associates of the Trieste Centre for the day when active research starts in their countries but no organized physics research. I stress once again, that these are impressions based on our experience with physics communities. No other significance should be read into them.

5. Modalities for Growth of Sciences

In the end, the growth of science in our countries is our problem. But in this article, I shall speak only of help which we may hope to receive from the scientific communities and others in the developed countries, for enhancing the practice of high level science in the third world? There is no doubt that outside help - particularly if it is organized - can make a crucial difference. First, regarding the work of individual physicists, this could take various forms: for example, the physical societies of developed countries could help by donating 200-300 copies of their journals to deserving institutions and individuals. They could waive publication and conference charges. In this context, the International Union of Pure and Applied Physics (IUPAP) has helped the Trieste Centre defray postage costs for distribution of old runs of journals; the American Physical Society has helped us with shared subscriptions to 31 physicists from 13 least developed countries.

The research laboratories and the university departments in developed countries could also help by building up Federation links with their opposite numbers and by financing organized visits of their staffs to the institutions in developing countries. They could create schemes like the associateship scheme I have already described at the Trieste Centre (whereby a high-grade physicist working in a developing country becomes part of our staff by being accorded the right to come to us three times in six years), at least for their own ex-alumni.

May I be forgiven for thinking in the following terms: that the physics institutions in developed countries may consider contributing in their own ways (in kind) according to the norms of the well known United Nations formula, whereby most developed countries have pledged to spend 1% of their GNP resources for world development. In the end, it is a moral issue whether the better-off segments of the science community should be willing to look after their own deserving but deprived colleagues, helping them not only materially to remain good scientists, but also joining them in their battle to obtain recognition within their own countries as valid professionals, who are important to the development of their countries and the world.

Let me now come to the question of the long term help the United Nations agencies can give in respect of building up scientific infrastructure, in their own areas of competence. I wish, in particular, to emphasise the role of the modality I am personally most familiar with - international centres of research. There is no question but that the developing world needs today, international research institutions, e.g. on the applied side, like the Wheat and Rice Research Institute; on the science side, centres like the International Centre for Insect Physiology (ICIPE) in Nairobi. Without

internationalisation, science cannot flourish; one cannot guarantee standards, guarantee keeping abreast of new ideas, guarantee a continual transfer of science by men who created it and who come to such centres, moved by their idealism.

Recently there have been created an international Centre in Mathematics at Nice, an international Science Centre in Sri Lanka, one in Turkey and another in Venezuela. An international Physics Centre, directed towards Latin America, was formally inaugurated in Colombia by its President a few months ago. Also the United Nations Industrial Development Organization (UNIDO) on the way to creating two international centres in the field of biotechnology, one located in Trieste and one in India. In biotechnology, we observe that modern advances in genetics started with the unravelling of the genetic code by Watson and Crick. Revealing as it does the basis for all known life, this has been one of the most synthesizing discoveries of the twentieth century, possibly of all times. I take pride in the fact that Walter Gilbert, who took a Ph.D. with me in theoretical physics at Cambridge in 1956 and then turned over to genetics, was among those who discovered elegant techniques for deciphering the genetic code. For this work, he received a Nobel Prize in Chemistry in 1980. In 1981 he went on to found a company, Biogen, which exploits, among others, techniques of genetic manipulation to manufacture human insulin. Again we observe the mutuality of high science and high technology.

To return, however, to the UNIDO initiative, the Executive Director of UNIDO, Dr. Abd El Rahman Khane of Algeria, who, on a visit to Trieste, had been impressed with our example of interfacing the basics of pure with applied Physics, conceived the idea that time was ripe for creating one or more

similar Centres for Biotechnology for the third world. On UNIDO's call, a competition was instituted. This brought offers from Italy, Spain, India, Pakistan, Egypt, Thailand and Cuba. Three inter-ministerial meetings were held to choose the location. In April 1984, Delhi and Trieste were finally selected for the location of a joint centre.

To my mind, one of the most significant features of the Biosciences situation is the fact that so many of the third world countries were so keen to make credible offers for it from their own resources. Personally, I was sorry at the decision of the assembled ministers who, by a majority vote, refused to accord to the losers of the competition - Egypt, Thailand, Pakistan and Spain - the status of even affiliated centres. These countries desperately wanted even a subsidiary status to share in the benefits of an internationalisation of their local efforts. I hope this will soon be rectified and these other offers will also be accepted. The point I wish to make is that even countries with moderate traditions of scientific research are beginning to show an interest in hospitating United Nations run Centres of Science.

In this context, to highlight the role which agencies like the World Bank or the International Monetary Fund (IMF) can play, consider the following quote from a recent biography of the World Bank by E.S. Mason and R.E. Asher: "UNESCO has been providing sensible advice on educational planning for years, before the World Bank entered the field ... Sometimes, some parts of this advice were accepted but there was a notable increase in attention given to educational planning when it became clear that some projects had some chance of being financed by the World Bank"

Besides educational planning, besides help with development of scientific agriculture, I would also wish that the World Bank could take it upon itself to emphasise to the developing countries that the fastest route to financial prosperity today lies with areas of Science based high Technology - for example, of micro-electronics, computer soft-ware and the like, and that the major investment needed in these areas is investment in creating scientifically highly-literate manpower. The day that the entrepreneurs (either in the government or the private sectors of developing country economies) begin to understand this, our economic salvation will start.

To summarize, my feeling is that almost every developing country has a scientific and technological problem which needs scientific expertise. I strongly feel that the United Nations system must take a lead with this legitimate movement towards internationalisation of science within the developing world for the developing world. The research centres do not have to be within the developing countries. Some years back, Dr. Henry Kissinger, the then US Secretary of State, on behalf of the US Government, promised to the third world a multiplicity of institutions which would include institutes to improve access to capital technology. He mentioned, in particular, an International Energy Institute, an International Centre for Exchange of Technological Information and an International Industrialization Institute. I am sure some day soon, the US Administration will carry these promises out, adding to each Institute, its due quantum of science.

Finally, let us turn to the role of the national aid-giving agencies.

My plea to the development agencies everywhere would be that they may take a long-term attitude to the growth of science. They exert an immense leverage which they must use to ensure that an adequate infrastructure is built in the countries they help and that the scientifc communities there are enabled, and allowed to play their rightful roles in the process of development.

In this context, one may remark that one of the well-tried modalities for science transfer is the creation of an International Foundation for Science for giving grants to individual scientists in the developing countries. An International Science Foundation with these aims was in fact created at the suggestion of Roger Revelle, Pierre Auger, Robert Marshak and myself in 1972 in Stockholm. This Foundation is currently supported by Sweden, Canada, USA, Federal Republic of Germany, France, Australia, the Netherlands, Belgium, Nigeria, Norway and Switzerland. Its funds are given for research in the areas of aquaculture, animal production, rural technology and natural products, to individual researchers in developing countries, in grants not exceeding ten thousand dollars per grant. Unfortunately, the total funds at the disposal of this Foundation are only two million dollars. A similar function is carried out by the Bostid organisation in the US which is supported by the Aid organisations. These initiatives do not cover other natural sciences nor is there any provision of funds for building up of scientific infrastructure.

With the Brandt Commission's recommendations on technology transfer in mind, in August 1981 I took the initiative of writing the following letter to the Heads of States participating in the Cancun Summit:

"I understand that technology transfer, with emphasis on problems of energy, will be one of the items for discussion at the forthcoming North-South Heads of States meeting in Mexico. Unhappily, most developing countries need help in building up scientific infrastructure at all levels and Science Transfer must accompany technology transfer if the latter has to take root in our countries. The scientific community in the North can, and I am sure will, be willing to help in building up the corresponding community in the South, provided it is mobilised for this".

I suggested the creation of a North-South Science Foundation to build up a movement towards Science Transfer, with funds at its disposal of an order at least similar to those, for example, disbursed by the Ford Foundation (between one hundred and two hundred million dollars a year). This Foundation should be run by the orld's scientific community for research and training for research, in basic sciences in developing countries.

I received polite replies of support to my plea from all Heads of States from the developed countries; from among the Heads of developing countries, only Mrs. Gandhi replied. (This unconcern perhaps emphasises once again the marginality of the scientific enterprise in the third world). Let me say, however, that such a modality is very much worth building up, particularly since the Ford Foundation, in a letter to the Secretary of the recently founded Third World Academy of Sciences, has told us that scientific research in developing countries is no longer a priority area for the Ford Foundation itself.

In sciences, as in other spheres, this world of ours is divided between the rich and the poor. The richer half - the industrial North and the centrally managed countries, with an income of 5 trillion dollars, spend 2% of this - more than 100 billion dollars - on non-military science and development research. The remaining half of mankind - the poorer South, with one fifth of this income of around one trillion dollars - spend no more than 2 billion dollars on science and technology. On the percentage norms of the richer countries, they should be spending ten times more - some 20 billions. At the United Nations run Vienna Conference on Science and Technology held in 1979 the poorer nations pleaded for international funds to increase their present annual expenditure of 2 billions to 4 billions. They obtained promises, not of two billions, not of one billion, but only one seventh of this. As we know, even this has never been realised and the United Nations Funding System for Science and Technology for Development is without adequate means. Contrast this with the situation in the military sphere. Each nuclear submarine costs 2 billion dollars and there are at least 100 of these in the world's oceans. Five hundred centres like mine at Trieste could be funded for a year for the price of one nuclear submarine.

Let me end by quoting from a great mystic of the 17th century - John Donne - a man who believed in the moral state of man and the international ideal: "No man is an island, entire of itself; every man is a piece of the continent, a part of the main; if a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manor of thy friends or of thine own were; any man's death diminishes me, because I am involved in mankind; and therefore never send to know for whom the bell tolls; it tolls for thee".

TABLE OF VISITS TO TRIESTE CENTRE WHICH ARE INDICATIVE OF THE SIZE OF PHYSICS COMMUNITIES AND THE SIZE OF HIGH LEVEL PHYSICS IN DEVELOPING COUNTRIES

TABLE I

	Number of Visits 1970-1983	Number of Post Doctorate Fellows since 1980	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84 **	Population (Million)*	GNP/capita US$ *
1 Argentina	220	2	8/23	2	54/85	28.2	2,560
2 Brazil	305	1	7/29	2	92/143	120.5	2,220
3 China ***	131	11	6/17	6	56/131	991.3	300
4 India	987	10	35/155	4	240/997	690.2	260
Total:	1,643	24	56/224	14	442/1,356	1,830.2	

* Excerpt from :
1983 World Bank Atlas - Population/capita figures
are those for 1981

** For main training-for-research activities
only

*** Joined the IAEA in January 1984

TABLE II

	Number of Visits 1970-1983	Number of Post Doctorate Fellows since 1980	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84**	Population (Million)*	GNP/capita US$
1 Egypt	537	1	10/43	16	119/296	43.3	650
2 Bangladesh	158	1	9/21	1	57/126	90.7	140
3 Korea	94	2	4/9	1	23/25	18.7	1,700
4 Malaysia	81	-	10/17	-	32/78	14.2	1,840
5 Pakistan	339	7	13/31	3	90/164	84.5	350
6 Singapore	34	1	1/4	-	7/14	2.4	5,240
7 Turkey	288	5	6/22	7	72/154	45.5	1,540
8 Mexico	169	1	2/6	-	40/69	71.2	2,250
9 Venezuela	87	-	1/4	-	15/27	15.4	4,220
Total:	1,787	18	56/157	28	455/953	385.9	

	Number of Visitors 1970-1983	Number of Post Doctorate Fellows since 1930	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84 **	Population (Million) *	GNP/capita US$
1 Algeria	73	-	2/5	1	13/32	19.5	2,140
2 Ghana	106	1	3/4	3	39/65	11.8	400
3 Kenya	34	-	3/9	-	14/27	17.4	420
4 Morocco	44	-	3/8	2	9/15	20.9	860
5 Nigeria	201	2	11/30	5	65/118	87.6	870
6 Sudan	96	-	6/10	2	22/28	19.2	380
7 Tanzania	32	-	3/4	-	5/10	18.1	280
8 Iran	118	5	3/6	3	22/46	40	n.a.
9 Iraq	84	-	1/4	1	19/28	13.5	n.a.
10 Jordan	74	-	2/4	2	12/13	3.4	1,620
11 Lebanon	85	2	2/3	2	9/11	2.7	n.a.
12 Saudi Arabia	47	-	2/7	-	6/18	9.3	12,600
13 Philippines	47	1	3/7	-	16/41	49.6	790
14 Thailand	84	-	3/5	-	45/98	48	770
15 Vietnam	9	-	2/3	1	5/8	55.7	n.a.
16 Sri lanka	106	1	4/13	-	46/97	15	300
17 Indonesia	106	1	2/6	-	43/89	149.5	530
18 Fiji	1	-	1/1	-	1/2	0.6	2,000
19 Chile	63	1	3/6	1	19/28	11.3	2,560
20 Colombia	69	2	3/9	-	27/57	26.4	1,380
21 Peru	77	-	3/9	-	37/108	17	1,170
Total	1,556	16	65/153	23	474/939	636.5	

TABLE IV

	Number of Visitors 1970-1983	Number of Post Doctorate Fellows since 1980	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84 **	Population (Million) *	GNP/capita US$
1 Benin	20	-	2/3	-	7/7	3.6	320
2 Cameroon	22	-	-	-	7/7	8.6	880
3 Congo	7	-	-	-	2/3	1.6	1,110
4 Ethiopia	14	-	-	-	10/12	31.8	140
5 Ivory Coast	7	-	-	-	3/3	8.5	1,200
6 Libya	57	-	1/4	1	30/40	3.1	8,450
7 Madagascar	26	2	1/2	-	9/12	9	330
8 Mali	25	-	1/1	-	5/9	6.9	190
9 Mauritius	13	-	-	-	4/10	1	1,270
10 Niger	7	-	-	-	0/1	5.7	330
11 Rwanda	6	-	-	-	3/4	5.3	250
12 Senegal	35	-	2/3	1	9/15	5.9	430
13 Sierra Leone	41	-	1/1	-	10/13	3.6	320
14 Togo	17	-	2/3	-	3/3	2.7	380
15 Tunisia	34	-	-	-	10/13	6.5	1,420
16 Uganda	23	-	3/4	-	6/9	13	220
17 Upper Volta	9	-	-	-	-	6.3	240
18 Zaire	21	-	1/3	-	4/7	29.8	210
19 Afganistan	11	-	-	-	3/4	13.3	n.a.
20 Burma	6	-	-	-	1/1	34.1	190
21 Hong Kong	16	-	-	-	1/4	5.2	5,100

TABLE IV , page 2

	Number of Visitors 1970-1983	Number of Post Doctorate Fellows since 1980	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84 **	Population (Million)*	GNP/capita US$
22 Kuwait	61	-	-	2	21/22	38.9	20,900
23 Syria	44	-	-	3	8/15	9.3	1,570
24 Nepal	47	-	2/7	1	30/64	15	150
25 Qatar	8	-	-	1	7/8	0.24	27,720
26 Yemen Arab Rep.	25	-	-	1	3/5	7.3	460
27 Papua New Guinea	10	-	-	-	3/5	3	840
28 Honduras	6	-	-	-	1/1	3.8	600
29 Costa Rica	24	-	1/3	-	8/16	2.3	1,430
30 Ecuador	9	-	1/1	-	2/6	8.6	1,180
31 Guyana	9	-	-	-	-	0.8	720
32 Bolivia	22	-	1/2	-	7/8	5.7	600
Total:	682	2	19/37	10	217/327	300.44	

TABLE V

	Number of Visitors 1970-1983	Number of Post Doctorate Fellows since 1980	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84**	Population (Million)*	GNP/capita US$
1 Botswana	2	-	1/1	-	-	0.9	1,010
2 Burundi	4	-	0/1	-	5/5	4.2	230
3 Cape Verde	1	-	-	-	-	0.3	340
4 Central Afr. Rep.	2	-	-	-	-	2.4	320
5 Gabon	4	-	-	-	0/1	0.7	3,810
6 Guinea	5	-	-	-	3/9	5.6	300
7 Lesotho	2	-	1/2	-	2/2	1.4	540
8 Liberia	1	-	-	-	0/1	1.9	520
9 Malawi	4	-	-	-	2/2	6.2	200
10 Mauritania	4	-	-	1	-	1.6	460
11 Mozambique	1	-	-	-	-	12.5	n.a.
12 Somalia	5	-	-	-	0/1	4.4	280
13 Swaziland	2	-	-	-	1/1	0.6	760
14 Zambia	7	-	1/4	-	2/6	5.8	600
15 Bahrain	2	-	0/1	-	2/4	0.4	8,960
16 United Arab Emirates	1	-	-	-	1/1	1	24,660
17 West Bank	5	-	1/1	1	3/5	n.a.	n.a.
18 Yemen PDR	1	-	-	-	3/5	2	460
19 Barbados	2	-	-	-	4/1	0.25	3,500
20 Cuba	2	-	-	-	1/1	9.7	n.a.
21 Dominican Rep.	4	-	-	-	3/4	5.6	1,260
22 El Salvador	4	-	-	-	1/2	4.7	650

TABLE V page 2

	Number of Visitors 1970-1983	Number of Post Doctorate Fellows since 1980	Number of Associates/ Applications	Number of Federated Institutes 1984	Applications accepted/ Applications received for participation in Centre's activities Jan. 81 - March 84 **	Population (Millions)*	GNP/capita US$
23 Guatemala	1	-	-	-	-	7.5	1,140
24 Jamaica	2	-	1/2	-	1/2	2.2	1,180
25 Nicaragua	1	-	-	-	-	2.8	860
26 Panama	1	-	-	-	-	1.9	1,910
27 Trinidad	3	-	-	-	0/1	1.2	5,670
28 Paraguay	1	-	-	-	-	3	1,630
29 Uruguay	4	-	-	-	2/4	3	2,820
Total:	78	0	5/12	2	32/57	93.75	

WORLD ORDER, DEVELOPMENT AND WORLD CRISIS

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1. Introduction

The proposition that we shall attempt to explore in this article is that the type of economic growth that the world - or rather part of it - has experienced so far cannot possibly continue in the future for at least two interrelated reasons.

(i) Consumption expectations with respect to material goods have tended to rise faster than production possibilities, the likely consequence being a permanent inflationary pressure and growing balance-of-payments difficulties. This inflationary pressure is reinforced by the simple fact that,

(ii) many natural resources are non-renewable and exhaustible, so that growth of "more-of-the-same" type cannot go unchecked. Technological progress has continuously extended the limits of resource availability, but these limits exist and to stretch them further or to find alternative sources requires huge and growing investment, while the costs of developing and adopting new technologies tend to rise rapidly, in both economic and ecological terms.

In this article we shall analyse point (i), concentrating on the international economic system with special emphasis on the international monetary system.

2. The World Economy, Development, and the International Division of Labour [1]

2.1 The International Dimensions of Development

The creation and evolution of the world economy is clearly related to the emergence and development of the capitalist system or market economy. [2] In the latter the relations that link together individuals as well as groups are largely asymmetrical, or unbalanced; such a situation not merely reflects initial inequalities, but is the natural outcome of the working of a market economy in which the main elements of the decision-making process have one by one become instruments of power for certain groups, while the preference structure of the market economy has been moulded so as to create demands which tend to promote the interests of those groups and to satisfy individually-centered needs rather than social needs. The phenomenon is the same at the national and the international level, the main effect of the existence of nations being that certain elements of the global decision-making process tend to be monopolised by, or concentrated in, certain nations, or tend to be monopolised by certain groups within certain nations. These are the same groups

1. This section summarizes part of the author's larger essay "International Trade and Economic Paper" in Towards a New World Economy, Fifth European Conference of the Society for International Development, Rotterdam UP, Rotterdam, 1972.

2. See I. Wallerstein, The Modern World-System, Academic Press, New York, 1974, pp. 14-15 and The Capitalist World-Economy, Cambridge UP, Cambridge 1979, p. 6.

which control the national decision-making processes.

Based on the same laisser-faire (minimal role of the state) and utilitarian (homo economicus) principles developed for the explanation of national systems, the international system is also assumed to be made up: (i) of equal units (equality); (ii) each interacting (that is exchanging value and/or information) with all the others (multilaterality); (iii) on equal terms (symmetry); and (iv) of socially undifferentiated units (homogeneity). The resulting structure is then characterized by circularity (that is, lacking hierarchical order or ranking) as assumed by the theory of comparative advantage and by most of the theorising in international economics and international law.

The concept of foreign aid was based on such a view of the world structure as it was meant to remove rapidly any temporary asymmetries which might have developed due to disequilibrating non-structural causes.

That the above circular model, although still underlying most of the recent literature, does not provide useful framework for discussing most of the present problems, is demonstrated by the concern which has started to appear about the role of the nation-state in a system increasingly characterized by supernational economic units.

A more realistic understanding of the development process may be obtained by replacing the circular model with an alternative model which possesses none of the characteristics of the circular structure, but instead exhibits features of inequality, bilaterality, asymmetry and social differentiation. In other words, a hierarchical structure in which verticality prevails over circularity.

This structure is the result of a gradual process of development of a system in which every success is turning a relationship a little asymmetrically constitutes a comparative advantage for the next encounter. Once created

asymmetric power-dependence relationships become the main cause of it perpetuation.

It is then difficult to speak of development as being mainly a national or regional phenomenon, i.e. a phenomenon which, by and large, is a function of the factors contained by, and conditions prevailing in, the subsystems. On the contrary, it seems that development really assumes a different meaning and has different implications for each of the countries (subsystems) concerned, and according to its hierarchical position. Thus, to the top countries development means the strengthening of the system's hierarchical structure; to those in a lower position the possibility of development rests on the previous elimination of the hierarchical structure. Even the emergence of some degree of circularity among the top countries of the international system does not guarantee the lessening of its overall hierarchical structure. Instead, the interactions between the two parts become even more asymmetric and the development of the countries at the bottom of the international system's structure is more difficult to achieve. The very process that brings (or has brought) one country after another into the market economy results in a demand structure which contributes to the creation and maintenance of an hierarchical structure which enables the countries at the top to extract values (economic and otherwise) from those at lower levels, and in this way to reinforce their position.

Countries thus become underdeveloped at the moment they enter the system at, or reach, a lower level, characterized by a gap between demand, however developed, and the available means to satisfy it - a gap which becomes smaller as a country moves towards the top of the hierarchy where more than the satisfaction of the demand for food, clothing and shelter is possible.

The increasing world integration is the engine for the creation and perpetuation of an hierarchical structure which simultaneously produces development at the top and under-development for the peripheral countries, and which excludes the possibility of a long-run tendency to equilibrium for the system.

In this way, development is a phenomenon which trancends national (and disciplinary) boundaries and whose inner mechanism can only be understood within a system more extensive than the national one, to which most studies have until recently been confined.

The conclusions that our approach seem to suggest are somewhat more disturbing than those derived from the usual approach. Given, a certain type of international division of labour at the core of the mechanism which produces and reinforces the domestic and international hierarchical structure, and given a complex linkage of interests among the ruling groups of both the upper and lower countries, development cannot take place without the weakening and ultimate elimination of such a structure and of the relative international division of labour.

2.2 The International Division of Labour

The hierarchical structure of the international system has its basis in the production of the market economy as a whole. A link is therefore established between the internal structure of each country and the production under-taken by it. It is also largely dependent on this internal structure, though modified by the injection into the international hierarchy, whether the country will move along the vertical hierarchical structure.

The specialization in primary goods resulting from the earlier international integration has established certain countries in the role of 'consumers', leaving to others

the function of producers, i.e. of demand creators, and leaving also to the latter the control (from what has then become the top of the hierarchy which meanwhile has emerged) of the overall production process of these underdeveloped countries.

The effects of the specialization in primary products on the development of the country's economy are sufficiently known not to require further discussion. What can be added is that where development followed an original specialization in primary products, that process was (with the exception of Japan the result of a 'colonization' which involved not only international movements of goods, but also those of capital and people, both assumed immobile by the theory of international trade. It was actually where the inflow of the latter factor, i.e. people, became predominant that economic growth followed quite easily, even when the original specialization in primary products was respected. Aside from the considerations that in those cases such a production was organizaed quite differently and often with a technology which made the productive process very similar to that we are used to associate with industry, it seems even more important to realize the positive role played by the demand structure which the colonizers imported with them. Thus, the new settlers were only geographically far away from the top of the international hierarchical structure; in fact,they were so very much a part of it that they usually succeeded in imprinting their demand structure on the various minorities found or created within each of these new countries.

The state being an objective element of the market economy for which it performs certain structural functions, it becomes relevant to establish which state performs them in an international system integrated on the basis of a certain type of division of labour.

If the state or the country in the process of being integrated is not able, for whatever reason, to take over these structural functions, they will necessarily be performed by the foreign producers with the help of their own states. As aresult, the country is placed at the bottom of the hierarchical structure.

It seems historically that most of the negative effects resulting from the process of integration of the various countries into the market economy have been avoided only be those countries where (i) immigration from the central countries constituted the most important inflow from abroad; and (ii) the state was able largely to control the process of transformation. Only under these two conditions have the countries concerned been able to reject the usual primary commodities vs. manufactures division of labour and so to satisfy at least most of the demand created by the very process of integration into the market economy.

Apart from the problem of why these elements have not been present in so many countries, the fact that such a division of labour was retained has further weakened the state's functions and has made it even more necessary, and justifiable, that these functions be seized by foreign bodies, these being either foreign states or foreign companies. It is then the production structure of the country, which in the case of underdeveloped countries is fixed by a certain type of division of labour between them and the industrial ones, which determines the role of the state, and the scope of its functions, and then the degree of power-dependence between the two groups of countries.

3. The Present Crisis

3.1 Introduction

The first challenge to the model outlined in the previous section came from the emergence of the socialist countries as a rather independent political and economic system which, although it curtailed interrelationships with the world economy, never totally opted out. Lately, these relationships have been growing quite fast, as indicated by trade, technology and financial flows records. Several countries have disengaged from the Western system, however, but not from the world economy, even if "capitalist penetration may be said to have become the sine qua non of the stability of bureaucratic socialism".[2a]

By definition, this alternative system excludes asymmetry and hierarchy since it was aimed at the harmonious development of all member countries. Whether it is perceived as such by many LCD's and whether in reality it has acquired some of the traits of the capitalist world economy are questions worth pursuing, but are clearly outside the scope of the present paper.

In the attempt to explain present problems, it is more useful to analyze the internal evolution of the capitalist world economy since the Second World War when the United Kingdom was replaced by the United States at the top. The reconstruction of Western Europe and Japan under US leadership dominated the 1950's and 1960's much more than the acquisition of independence by most Third World countries. The 1970's saw the US position being challenged by the EEC and Japan.

2a. J. Camilleri, "The Advanced Capitalist State and the Contemporary World Crisis," Science & Society, XLV, 2, Summer 1981, p. 133.

The world economy lost some of its verticality as the rigid hierarchical structure gave way at the top to a kind of circular model, in which the role of the US increasingly became the primus inter pares. Meanwhile, the alternative socialist system expanded, growing in importance economically and even more militarily. The appearance of some circularity at the top of the world economic system, however, did not positively affect the lower strata of the hierarchical model; their situation tended to deteriorate during the 1970s as their distance from, and their dependence on, the upper countries increased. The spreading appeal for national or collective self-relaince was connected to this structural evolution of the world economy.

The "crisis of development" and the "crisis of foreign assistance" dominated the 1970s, which also witnessed the parcelization of the Third World by the emerging EEC and Japan against the "global" interests of the US which has been at the basis of their earlier support for the Third World struggle for independence.

The multipolar system that came into being had the following consequences:

(i) Curtailment of US economic and military pre-eminence, exemplified by the end of dollar convertibility and by the American defeat in Vietnam, and therefore increased instability of the whole system;

(ii) Growing East-West interrelations, especially between Eastern and Western Europe, with resulting detente but also a lowering of the defence stance by many West European governments and acceptance of neutrality or demilitarization (or Finlandization) as a viable option by growing sections of their populations;

(iii) Further marginalization of LDCs and their problems, as demonstrated by the reception given to the concept of the New International Economic Order, after

earlier interest shown under the OPEC shock, and the failure of the North-South dialogue.

With the 1980s many elements of the multipolar system seemed to be challenged by the US decision to regain its military supremacy and to consolidate its leadership over the Western World.

3.2 The Concept of Crisis

The concept of "crisis of capitalism" was elaborated at the end of the 19th century by economists of Marxist derivation and by radical sociologists, and with the First World War it became central to political discussions. As the concept of development, it can only be understood within the framework of the world economy. According to Marx, Lenin and Schumpeter, to mention only the main contributors, the crisis is not merely negativity, i.e. a malfunctioning of the system which lowers production and accumulation, but it is an ambivalent phenomenon through which some classes, economic groups or countries can reinforce their respective positions. In other words, the crisis is the rationalization of the national or international system on behalf of particular interests.

Keynes considered the crisis a kind of disease, a psychological impediment between disposable productive factors and the needs which could be generated if those factors were fully utilized; like underdevelopment, the crisis appears to be an incident on the road to prosperity and progress. [3]

3. J.M. Keynes, The General Theory of Employment, Interest and Money, MacMillan, London 1964, pp. 313-324.

As Keynes could not see the crisis as a phenomenon involving the whole international capitalist system, the remedy against such an incident was to be the expansion of production or as Ford has already proclaimed, "the immediate cure for depression is told in one word - quantity - quantities of goods pushed out into the world". [4]

If the private sector was not quick to act accordingly the state had to intervene to foster production and to redress income distribution so as to enlarge the purchasing capacity of the masses. Socialist demands for a fundamental reform of the system which also serves the producers.

In Hitler's social-national economic planning, this was a main element. The principal result of the application by the industrial countries of this approach - without forgetting the relevant contribution of WWII - was not the elimination of business cycles for a lengthy period, but the generalization of the 'more-of-the-same' development model whose expansion seemed to have no limits. Given its economic and political success in the DC's proposals and attempts were even made to extend this model to the Third World, where the existence of severe physical, environmental and ecological constraints finally had to be faced. Deterioration of the quality of life in the DC's and the growing costs of production - including those of labour pressured by the comsumerism drive, at the same time alienated by the nonsensical production - are clear signs of the gravity of the situation.

4. H. Ford (in collaboration with S. Crowther), Moving Forward, W. Heinemann, London, 1931. p. 7.

The internationalization of production i.e. the all pervasive and growing role of the multinational corporations (MNCs) appears in the generalized expansion of production of similar commodities to be 'pushed into the world" which, therefore, is becoming less and less differentiated.

In this sense, while the "great crisis" created the present international economy, the current crisis might perhaps mark the end of an epoch but not necessarily of the system. In fact, the tendencies reviewed in the next section seem to indicate a return to the past, through the enforcement of revisited classical theories, rather than a movement towards the crisis of the system of which some still dream.[5] It is also a crisis which concerns the DCs and mainly Europe, although its management especially in our interpretation - will have fundamental consequences also for the LDCs and ultimately for the CPEs.

3.3 Structural Problems

The adjustment policies by the DCs in order to face the 1973 oils crisis apparently ended-up in an unprecedented drop in industrial production and in continuously high rates of inilation and unemployment. The DCs crisis however, has deeper economic and social roots and the oil problem has only helped to accelerate a process that had started earlier on, determined mainly by the following

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5. J. Palmer opens his contribution "Economic Crisis" (The Socialist Register 1980, R. Miliband and J. Saville, eds. Merlin Press, London, 1980) remarking that 'the word "crisis" is one of the most overworked in the socialist dictionary. He instead recognised that "there is a problem of ecologically balanced and resource-conscious development to which socialists have been inadequately sensitive".

factors.[6]

(i) Saturation of market growth possibilities for manufactured goods. During the 1950s and 1960s, final demand, both qualitative and quantitative was directed primarily towards manufactured products. This had a positive effect on DCs rate of growth, as the multiplier of manufactured products tends to be higher than that of agriculture and services. Decreasing real prices of manufactures encouraged an expansion of consumption and therefore of production. During the 1970s, relative price dynamics underwent a change: manufacturing costs started to increase faster in real terms as a result of higher costs of energy and raw materials and of slower growth in labour productivity. The result for the DCs is a high level of unemployment for all factors of production and an exceptionally high level of indebtedness for LCDs (see viii).

(ii) Increasing incidence of services in final demand and a consequent decline in capital efficiency. In fact, services require a higher level of capital expenditure per unit of output than do manufactures. To obtain growth rates comparable to those of the earlier post-war period requires a proportional increased savings and capital investments, while

(iii) on the one hand, the enormous expansion of all government activities and growing budget deficits have been absorbing a substantial and increasing share of potential savings, more for non-productive uses and/or redistributive purposes than for actual investment;

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6. ENI (Ente Nazionale Idrocarburi), The Interdependence Model, Seminar 'Development Through Cooperation', Rome, April 1981, vol. 1, pp. 74-79.

(iv) on the other hand, the private propensity to save and to invest is gradually diminishing due to inflation and uncertainty in possible returns. In fact there is an unmistakable decline both in the rate of return on invested capital manufacturing and in the share of profits in total output; the latter is also due to

(v) increased pressure for income redistribution, namely, for labour's greater share of total income as well as for a redistribution within labour in favour of lower skills. Such as redistribution has favoured a rapid increase of labour-saving rather than capacity expanding investment, and has in turn also lowered the propensity to save. The result has been higher unemployment levels, reinforced by

(vi) a new international division of labour at the world level, forced by rapid industrialization of the LDCs (the NICs) and also fostered by the growing labour and environmental production costs in the DCs, together with the modification of the relative prices of manufactured products due to the oil price increases of the 1970s. The needed world-wide redistribution of productive capacity requires profound restructuring, new laboursaving technologies, and consequently a high level of investment in the DCs. In a context of slow growth of output and investment, however, restructuring only generates higher unemployment levels. This new division of labour is brought about largely by the MNCs; the resulting

(vii) rapid internationalization of production, with consequent world-wide distribution and marketing of manufactures and services, tend to reduce the autonomy of national authorities. MNCs can evade their checks and controls without being subjected to the regulations of any international agency, as are governments. The Euro-dollar and Euro-bond

markets are also closely connected to the operations of the MNC s and their expansion, and both institutions are definitely above the reach of national governments. The international decision-making structure which they have constituted has transformed a considerable part of international trade into intro-company (about one-half of world trade is estimated as being intra-firm sales) taking place at transfer prices, i.e. accounting or imputed prices, which are internal to the firms themselves. As such prices are not determined by market forces and bear little relation to costs of production. MNC s also control substantial parts of international capital flows, so that their impact on the various national balances of payments and currency values has been quite relevant. All too frequently, they have helped to create or amplify imbalances among the leading currencies, and consequently have enhanced

(viii) the instability of the international monetary system. The shift to fluctuating exchange rates, intended to enable more independent national monetary policies, has slowed down the process of international integration which prevailed under the fixed exchange rate system built by Bretton Woods, while the lack of co-ordination of national monetary policies and the growing private liquid assets have encouraged speculative behaviour in the currency markets. The consequent climate of uncertainty is detrimental to the development of world trade; this hampers the recycling of the OPEC surplus and also the financing of non-OPEC LDCs imports, whose outstanding long term external indebtedness approached $ 700 billion by the end of

1983, rising from about $100 billion in 1973.[7] There is widespread concern that large-scale disequilibrium in trade and payments will characterize the world economy during the 1980s and, in turn could have a disruptive consequence on economic growth and employment in the DCs as well as LDCs The resulting increased instability has had a dampening effect on production and investment and has accelerated, rather than slowed down, the international transmission of inflationary pressures.

3.4 'World Order' and Stagflation

The disparate and increasing usuage of the expression 'world order' and the proliferation of books, articles and documents on this topic all signal the end of the post-war system, which was built on the US hegemony. Most people agree that the political-economic order in general, and the monetary order in particular, tend to reflect the overall distribution of power and the struggle to modify or to retain it. In a real sense, therefore, "the world monetary crisis is basically about what economic, military and political role the United States should play in the world".[8] The US saw its hegemonic power badly eroded in the 1960s and 1970s and has since struggled - at times more forcefully than others - to regain it. The crisis of resources and the phenomenon of stagflation cannot be understood except in this context and without explicit relation to the dollar, i.e. to the international

7. IMF, World Economic Outlook, Occasional Paper 21, Washington May 1983, p. 67 and Table 32.

8. The New York Times (16 September 1971), 34, as quoted by H.O. Schmitt, 'International Monetary System: Three Options for Reform . International Affairs (April 1974), 50, 2, p. 210 "There is good reason to suggest that the crisis of world capitalism is inextricably intertwined with the decline of American power," Camilleri, op.cit, p. 141.

monetary system. In terms of international economic crises, there are two types of integrated monetary system - highly centralized, (or hegemonic) and the plural; a sub-distinction of the latter could be considered the system of blocs. There is also a disintegrated one, namely, monetary chaos.[9]

In the hegemonic system one country issues the reserve currency and consequently is exempt from the need to remain in equilibrium, although it loses the exchange rate as an instrument of economic policy. The system generally suffers from inflation as "the hegemonic power is unable to resist running excessive deficits in order to bolster its political, military, or economic position." This worked for the United Kingdon until the First World War, but it is now difficult when a plurality of industrial power tend to resist any imposed international division of labour on which to base the equilibrium of the whole system.

The rationale of the plural system rests on the "inevitable corruption of any national hegemony, plus the inevitable resistance of powers." This system may be multilaterally managed or automatic. The first "tries to combine plural equality with centralized control", but in fact either prevents agreements from being reached or covers for the hegemony

9. For a similar classification and most of the substantive explanation see: D.P. Calleo, "The Decline and Rebuilding of an International Economic System: Some General Considerations," in Money and the Coming World Order, D.P. Calleo (ed.), New York U.P., New York, 1976.

of one power. Multilateral institutions thus flourish either for highly technical matters or are limited to members who share common situations or interests. The autonomic plural system is organized around certain accepted rules of the game which, as in the pre-WW1 system, are concerned more with stability than with growth and employment because too much emphasis on the latter would make such a system unworkable.

A system of blocs - Calleo's bet for the future - requires "a mutual renunciation of hegemonic pretensions... and a plural world political-economic system, with interdependence regulated by a shared concensus among self-determining subsystems... A balance of power equilibrium among the major centers could be maintained by a mixture of floating and controls."

To conlcude, the two main types of international monetary system both tend to be inflationary either because like the hegemonic one, it is structurally so, or because of the neglect of stability conditions in the plural system. Such a neglect becomes logical - or necessary - in view of the excessive fiscal and monetary policies of the nation-states. Politically organized rising expectations, whether national or international, shape economic policies which may actually either hinder re-equiliberating tendencies within the international economy or require too many scarce resources.

It remains to be seen whom this permanent inflationary pressure benefits and why it has lately been accompanied by an unprecedented rate of unemployment.

3.5 From the Convertible to the Inconvertible Dollar Standard

The official suspension of the convertibility of the US currency declared on 15th August 1971, perfected the *de facto* dollar standard initiated at Bretton Woods.

Placed at the centre of the monetary system, US inability to adjust its exchange rate meant that the discipline of the balance of payments which has so often been forced on all countries was ineffective on the US economy. Other nations were left the alternatives of accepting the US rate of inflation or of accumulating dollars in their reserves. "In effect, therefore, the central bank of one country was placed in a supra-national role, exerting a large influence on monetary conditions in other countries without necessarily being responsive to their needs." Furthermore, all other countries had "to accept whatever capital and other transfers the United States might choose to disburse abroad, for whatever purposes, and either accumulate inconvertible dollars, or inflate sufficiently to allow American producers to earn them back." In fact, this meant an "implicit underwriting of American investment in Europe and of the large increase in overseas expenditures associated with the Vietnam war".[10]

In order to defend its reserves and safeguard its freedom of movement, i.e. to regain the exchange rate as an instrument of economic policy, the US suspended dollar convertibility and accepted the floating exchange rate which, in principle should allow countries varying inflation rates, but in fact enable "American producers to expand at the expense of others wherever increased

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10. Schmitt, *op.cit.*, p.197 and 199

American transfers abroad, of any kind, required financing." [11] The danger that the floating rates also "offers a continuous 'invitation to economic warfare as countries manoeuvre their exchange rate against each other'", [12] is less real because the US is the only country which is really free to devaluate its currency, an action which has stronger inflationary effects on the world economy than on the US. At the same time, the US has retained the seignorage over the supply of the instrument for international payments. Under the convertible dollar standard, the seignorage is equivalent to the net amount of money put at the disposal of the world economy by the US, i.e. the deficit of the official settlements balance. While the rapid growth of the Euro-dollar market has rendered less precise this equivalence, there is no doubt that US seignorage has also increased. [13]

Under the convertible dollar standard, however, US leadership was accepted also because that country supplied the world with a common good, namely economic stability. In the 1970s the reduction of its commercial pre-eminence and the resulting commercial deficit not only

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11. Schmitt, op. cit., p. 197 and 199.

12. R. Roosa, in M. Friedman & R. Roosa, The Balance of Payments: Free Versus Fixed Exchange Rates, American Enterprise Institute, Washington, 1967, p. 50 quoted in Schmitt, p. 210.

13. The US balance of payments official deficit averaged $0.6 billion annually in the 1960s and 15.0 billion in the 1970s. See R. Solomon, "Techniques to Control International Reserves" and other essays in R. Mundell and J.J. Polak, The New International Monetary System, Columbia, UP, New York, 1977.

curtailed US ability to provide the common good, but made it the direct cause of troubled international financial relations which, in turn, generate economic imbalances and world stagnation. Free of any external constraint, at the beginning of the 1970s the US start to reflate, thus, contributing to the first acceleration of the inflationary process at home and abroad. The following devaluation of the dollar helped to contain the US commercial imbalance and to eliminate any potential monetary role of gold, as in the late 1960s the US had accepted the creation of SDR only to prevent sufficient support being given to the French proposal for the rehabilitation of the role of gold.

More recently, although the inconvertible dollar standard makes the financing of oil imports easier - i.e. less costly - for the US, the reduction of its dependence on foreign oil is contributing to that country's recapturing of commercial leadership. US competitiveness has been enhanced by increased energy costs, while the continuous inflow of petrodollars helps to finance its development of alternative sources of energy and US direct foreign investment, including its rising penetration of NIC's manufacturing sector.

The higher interest rates applied by the Federal Reserve Bank enhances US ability to obtain resources from the world economy but, at the same time, by making the revitalization of most DCs increasingly difficult, perpetuates its instability. Failing to provide the stability of the world economy, and so justify US seignorage, [14] this common good is increasingly rephrased in terms of defence. The cold war has already once proved a very useful instrument to establish US hegemony: it might be useful now to regain a similar position.

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14. C.P. Kindleberger, "Systems of International Economic Organization", in Calleo, op. cit., pp. 37-38.

The re-establishment of US competitiveness limits the growth of imports from other DCs, and consequently has a depressing effect on the latter. The same effect is caused by the OPEC balance of payments surplus: directly because it reduces the domestic demand of oil-importing countries, but also indirectly because it limits their overall importing capacity. Ultimately, the oil problem is one of financing the balance of payments of importing countries, which roughly include Europe and Japan and some LDCs. This means then that the present crisis, more than a world crisis, is limited to certain areas.

To sum up, understanding of the present international crisis seems to rest on two main elements.

In the short run DCs, including the US, which face persistent balance of payments deficits and attempt to limit their imports, cause a lowering of their own income as well as that of the rest of the world. Contrary to what happened in the 1930s however, the US can easily finance its deficit with dollars while some LCDs have had access to the private financial markets. The financial constraint has therefore burdened European economies most of all. Of course world demand could be sustained by expanding official international liquidity. The sources for the creation of the latter - SDR enlargement of IMF quotas, etc. - are controlled by the US,[15] which -is not necessarily interested in halting a crisis of which it is largely the cause but also the main beneficiary.

In the longer run, the revitalization of the world economy finds an insurmountable limit in the availability of non-renewable resources and in growing labour costs once unemployment levels start to be seriously reduced.

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15. See also R. Parboni, The Dollar and Its Rivals, NLB and Verso, London, 1981, pp. 78-9.

The danger of an increased inflationary pressure as the result of an extra creation of official international liquidity, could be reduced by linking it to (i) massive investment in the production of and search for LDCs resources, and (ii) the financing of relative stabilization schemes.

3.6 Domestic Policies

Policies which affect the world economy are still decided nationally. In terms of their international perspective, three schools of thought can be distinguished, which a) perscribe economic policies, directly or indirectly designed to affect national output, employment and the general price level; b) measure the relative merits of the governments monetary and fiscal policies by their contribution to national economic goals; and by implications c) assess the role of the state.[16]

(i) The Keynesian school subordinates the goal of the world economic stability to national policies designed to achieve full domestic employment. Such full mobilization of national resources in a government-shaped economy tends to neglect price stability and in fact "one predictable result of neo-Keynesian demand management policies has been inflation of the general price level", first domestically and soon internationally, and "a decisive decline in the primary of the private market economy".

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16. See "The Creation of International Monetary Order", L.E. Lehrman, in Calleo, op. cit., mainly 77-101.

(ii) The monetarist school advocates the principle of price flexibility in a free market economy where the role of the state should be reduced to a minimum. In effect, however, it "elevates the state over the market by asserting the supremacy and independence of national monetary policy", by which "the sovereign nation state can shape the domestic market" and can have "more natural and efficient influences an output and resources allocation than the neo-Keynesian fiscal policies". Under the name of 'fine tuning', however, "an interventionist monetarism often combines in national policy with an interventionist Keynesianism. The latter dogma encourages government deficits, the former finances them." Furthermore, many American monetarists "do not perceive that.... the short run objectives of national monetary policy, especially that of a great power have serious global implications.... because the dollar is a reserve currency and, in its role as world money, serves as the basis for other national currencies." Therefore, "reasonable men might well wonder why management responsibility for a common world currency is permitted to gravitate to a single government, the national self- interest of which may only rarely coincide with an efficient and equitable distribution of world economic benefits."

(iii) The classical liberal economic theory, nowadays not often seriously considered, which "called for balance in the government budget, reduction of certain taxes in the long run interest of national economic welfare.. sound money and private market sovereignty.. maintained by strong but constitutionally limited governments... Real resources had to be earned... and an ordered society was not organized to satisfy men's infinite desires but rather to establish and maintain the public interest."

Although more convinced than the other two schools that national economies tend to become integrated internationally,the classical approach "provides the definite objection to a national currency serving as the world currency is either a fixed or a floating exchange-rate regime." And while many neo-Keynesians and monetarists believe that floating exchange rates can effectively uncouple a national monetary system from the world system and therefore prevent the international transmission of inflation, there is no doubt that "as long as the world currency has a national identity, its value will be determined largely by the monetary policies of a single dominant country, the self-discipline of which cannot be taken for granted." In fact, the floating exchange rate system has been adopted only when the US decided it was convenient for it to do so. This system is potentially an instrument of nationalistic monetary policies which may become either " the indispensable tools of resurgent economic insularity", as Lehrman suggests, or the instrument to build up the economic bloc foreseen by Calleo.

What is certain is that these competitive nationalist policies tend ultimately to depress the economics concerned. As the US is much less conditioned by the balance-of-payments constraint, it can still obtain a rate of growth higher than that of the capitalist economic system as a whole. Under these circumstances it becomes difficult, however, to maintain the unity of the system threatened by the frustrations - and therefore possible aggressivity - of the various DC squeezed between the US resurgent hegemonic power and the robust competitiveness of the NICs. The growing economic interdependence of West Europe with its

Eastern counterparts [17] is resented and opposed by the US. At the Ottawa summit the proposed Soviet pipeline - a $15 billion deal which could be very useful to the latter's ailing steel industry - was at the centre of discussion more than the American high interest rates. Soviet methane can be exchanged with Western European manufactures, while American coal - as proposed by the US - cannot be bought in the same way. The Middle East crisis offers another example of these tensions internal to the Atlantic economy: Western Europe backs a solution more favourable to the Arabs because Israel's containment would also imply the containment of US economic presence in the rich markets of the Middle East. Furthermore, Arab financial resources could be very useful to Europe and to the latter's penetration of Africa.

The rediscovery of a common enemy - real or alleged - then becomes necessary in order to contain the disruptive effects that such contradictions could have on the present world order, and to justify the appropriation of resources that this order allows the hegemonic power to continue without however, providing any common good.

4. Conclusions

As national economies are increasingly integrated into the world economy, the cause of the present crisis must be found at the national and at the international level, a distinction which is becoming difficult to retain even for purely analytical purposes. The crisis has seriously undermined the confidence in the present international economic order and in the welfare state into which, since the Great Depression, most DCs

17. While Western Europe's commercial exchanges with Eastern Europe have been growing, its interdependence with the US has not.

socio-economic systems have been moulded. Both the reconstruction since the Second World War and the building-up of the welfare state, have been the sources of the unprecedented economic development of the DCs and have also required the expansion of the role of the state. These Keynesian state-interventionist demand managed economies - often badly imitated by the LDCs have turned into stale-mate systems of corporativist interests capable of deterring each other rather than of co-operating for the general benefit.

This has contributed to the decline of the rate of profit and of its share in total output, and consequently has opened up ideological space for the conservative-monetarist revival aiming at re-establishing more favourable conditions for profitable investment and at reducing the growing costs of the welfare state.

Dissatisfaction with the performance of national governments is also due to the fact that the nation state's growing inability to satisfy the ever-increasing demands results partly from a profound process of internationalization which reduces its autonomy. [18] Meanwhile, economic expansion has become less likely - or even less desirable - because of the rising costs of production and of the declining weight of the manufacturing sector. The supply-site approach only emphasizes the need to produce before creating the required demand, i.e. to reduce the growth of demand, primarily social and public, and to liberalize the economy by diminishing the role of the state. However, it is mainly the redistributive and social functions of the state which are curtailed, while some obsolete and unprofitable economic sectors still require, and obtain, subsidies and protection to counteract other DCs or NICs competitiveness, even if such state interference is bound to fuel domestic inflation.

18. A. Lindbeck, "The Changing Role of the National State," Kyklos. 28, 1, 1975, p. 36.

The process of internationalization of production has created its own decision-making structure based on a series of multinational institutions and organizations, private as well as public, closely interacting among themselves: a process which hampers and alters the task of nation building which still faces many LDCs.

The exploitation of the crisis by the US in its effort to regain its hegemonic position within the world economy, tends to lower the growth potential of most DCs and LDCs. US rearmament, also meant to revitalise its economy as did the Second Wrold War requires huge quantities of non-renewable resources, the demand of which by the rest of the world is kept low while the economic recession continues. Economic growth of "more-of-the-same" type clearly shows its limited applicability, both for civilian and for military production. Even if a natural resource rich country like the US finds itself in a more favourable position, the decision to increase the production of guns must involve the politically dangerous substantive reduction of butter, i.e. social benefits.

The crisis has also been used to justify the smaller official transfer of resources to LDCs. In fact, the industrialization of NICs has been largely financed by international private money.

The adoption of conservative-monetarist policies by a growing number of governments represents the end of the social-democratic project, both in DCs and LDCs. In this sense, the present crisis marks the end of an epoch.

SOUTH-SOUTH CO-OPERATION WITH PARTICULAR REFERENCE TO TRANSFER OF TECHNOLOGIES

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1. The idea that the developing countries should individually and collectively rely to a greater extent on their own resources appeared rather recently and without much prior theorizing. It could be related to the political awakening and common actions taken by the non-aligned and other developing countries, particularly since 1976. In view of the encouraging successes of political decolonialization, and as these countries recognized the limitations of the various "universal models of development" and the "appropriate technology" strategies they have, over the last decade, developed their own "international development strategy", and attempted to formulate it in the context of a new international economic order. From a historical point of view, the concept of self-reliance is actually nothing new. It can be said that not one of the present-day developed countries achieved their level of development without utmost mobilization of all its resources, while at the same time making full use of the positive effects of international economic cooperation.

Under the present conditions of ever-increasing interdependence of the international economy as a whole, the DC's cannot forgo cooperation with the developed world. However, they are in a position of assymetic dependence on the developed world and they must create conditions to enable themselves to take the best possible advantage of international trade as an important (external) factor of their socio-economic transformation.

Up to the present no satisfactory scientific definition of the concept of DC's self-reliance has been produced. We feel that such a definition would, above all, have to cover the following basic features:

a) Autonomous decision-making on all vital economic questions, both on those related to domestic economic issues as well as to foreign economic relations;

b) The establishment of a structure of the national economy which will be capable of generating those impulses on which the success of socio-economic development depends, in accordance with the prevailing system of values of the given country.

This postulates, among other things, the capacity of a developing economy to mobilize all domestic resources which will, combined with foreign economic relations (on a level of as great equality as possible) ensure the implementation of the adopted development strategy. Irrespective of the considerable differences in the conditions in the various categories of developing countries, as well as in their specific foreign trade policies, the concept of greater self-reliance can in no case be considered identical with autarchy.

In fact, this concept does not call for any significant reduction of the DC's global economic cooperation with the developed countries, but implies, above all: (1) a change in the nature and structure of these relations, in order to achieve greater equality between partners and; (2) above all, a significant increase in mutual cooperation among the developing countries.

While the concept of collective self-reliance gains in importance as a development strategy of the developing world, it is becoming increasingly obvious that DC's mutual cooperation depends not only on their overcoming of economic under-development and on more equitable relations with the developed world, but also on the extent to which their development policies themselves create conditions for fruitful cooperation at the sub-regional, regional and interregional level. This indicates the strong interdependence between domestic socioeconomic development, DC's mutual cooperation, and the struggle for their international economic emancipation.

2. In the search for theoretical foundations for the concept of DC's greater, collective self-reliance, most of the modern contributions to the theory of international trade have been studied, and particular attention was devoted to the theory of economic integration. While discussions on the former theory do not devote appropriate attention to this specific problem, the theory of integration does consider the integration processes among these countries fairly closely. One could speak of a still young subdiscipline (or school of thought), which deals with the problems of DC's economic integration.

We feel that the theoretical thinking on this topic over the past 20 years can be divided into three phases, which are characterized by the following approaches: market integration, complex integration, and functional integration.

The first of these (which has few supporters left today), applies the classical concept of integration to the developing countries, without any adaptation. The followers of this approach interpret economic growth as the essential problem for DC's (discounting development as a process of complex socioeconomic transformation). In their view, economic growth would be accelerated by integration through liberalization of intragrouping trade, that is, through extension of the market.

The second approach takes into account the specific development functions of integration under conditions of economic underdevelopment and recognizes the factors which prevent successful operation of the market integration. Its advocates propose a complex policy of integration designed to encompass all phases of the economic processes and all areas of economic policy, and therefore postulate strong state intervention.

It was only the third approach which freed itself from the limitations of foreign trade theory and models of integration designed for, and in the developed world, and is strongly based on modern views of development theory. Although there are considerable differences betwen the advocates of this approach, common to them all are: a critical attitude to the customs union theory, and strong links with a variety of (not only economic) social sciences. This school has produced exceptionally useful work which does not offer the DC's rigid formulas and recipes, but provides flexible alternative instruments and mechanisms whose application the developing countries can adapt to the given conditions in each specific integration process.

The following typology gives a brief comparative survey of the major characteristics of these three approaches:

THE MARKET APPROACH	THE COMPLEX APPROACH	THE FUNCTIONAL APPROACH
Theoretically based on the customs union theory and on the neo-classical school of foreign trade.	Theoretically based on the modern theory of integration and on the protectionist-interventionist schools of foreign trade.	An interdisplinary approach closely linked to development theory is being applied, since foreign trade theory is considered too narrow a framework for studying integration, particularly in the Third World context.
The process of integration is interpreted as a gradual merger of national markets through trade liberalization, and the final goal is the establishement of a common market.	Integration is defined as a process of active establishment of a regional economy, which calls for harmonization of economic and social policies, so as to achieve the establishment of an economic community or even an economic and political union.	Integration is one of the DC's development strategies and it is not limited to the unification of markets, and it also need not strive for as high a level of integration as possible in all cases. This approach is very flexible in the choice of goals and instruments, while the development of economic interdependence must be based on the production sphere.
No specific attention is paid to the distribution of benefits among the countries, since it is expected that a common market will ensure the optimal alocation of resources, which is to the benefit of all partners; automatism of the integration process does not call for any specific joint institutions, and the sovereignty of the tries remains practically untouched.	Back-wash effects to the detriment of the economically weaker countries are expected, but it is also expected that this will be satisfactorily compensated by anti-polarization measures which would have to be taken by the appropriate joint institutions; this, however reduces the sovereignty of integrating countries.	Polarization is a concomitant feature of integration and it can only be avoided by a systematic policy of preferential measures to the advantage of the less developed countries, but this calls for strong common institutions and requires favourable political will, that is, solidarity on the part of the more developed countries in the integration grouping.
The conditions for successful integration are defined along the lines of classical theory (i.e. fairly restrictively).	If a certain group of countries decides on complex integration and introduces the appropriate policies, the conditions for succesful integration of the classical theory need not be considered fully applicable.	The conditions for successful integration as formulated in classical and in modern integration theory are rejected, although individual elements do remain relevant in specific context. The main condition is functional adaptation of the general model and specific integration policies to the given grouping and existing circumstances.
In their expectations of static and dinamic effects the adherents of this approach were initially optimistic with regard to the benefits which integration could bring to the developing countries, later appeared increasing doubts.	In the expectation, above all, of dynamic efects, these authors rather optimistically assess the potential benefits of integration.	Recognizing significat desintegration factors (of integral and external origin), these authors stress that integration is not a panacea, but they still attach great importance to this aspect of development strategy.
In accordance with its generally liberal position, this approach advocates as little state intervention as possible.	Only countries where the role of the state in economic life is important can successfully accomplish complex integration.	The uncontrolled position of the private sector in the integration processes among the developing countries is in many cases one of the major causes of failure. Efficient state intervention is essential for successful economic integration.
It is expected that regional integration will damage the world economy less than protectionist policies at the national level.	Priority is given to the interests of the integration groupings (and not to abstract prosperity for the world as a whole); however, the dynamic efects of regional integration are expected to have a positive effect on the world economy.	In view of the antagonistic division of the world into developed and developing countries, the integration of the latter is seen as an instrument of their collective self-reliance and a factor of gradual transformation of the world economy along the lines of a new order. All this - along with the dynamic effects of regional integration - is of benefit to the world community.

3. According to the documents of the non-aligned and other developing countries, the goals of their mutual economic cooperation could be defined as follows:

a) to take full advantage of the existing level of complementarity and to gradually eliminate intermediaries (from the developed world) from DC's mutual economic relations;

b) to develop new areas of economic complementarity and to set up joint productive capacities;

c) to strenghten their bargaining position vis-a-vis the developed world;

d) to set up mutual relations in accordance with the principles of the new international economic order.

4. The data on trade among developing countries - which constitutes the major part of their overall mutual transactions - indicates a stagnation up to the end of the 1960s. Thus in the period 1970-72 trade among the DC's accounted for 20.2% of their total exports, and for only 3.6% of total world exports. However, in the course of the past decade DC's mutual trade experienced the most dynamic growth among all categories of international trade so that in the period 1980-1982 these shares rose to 27.5% and 7.5% respectively.

Table: The relative importance of developing countries' intra-trade, 1970-1981
(Based on export matrix)

Year	Developing countries mutual exports ($ US billion)	Percentage share of developing countries mutual exports in their total exports	Percentage share of developing countries mutual exports in total world exports	Quantum index of developing countries mutual exports (1970 = 100)
1970	11.0	19.6	3.5	100
1971	12.2	20.1	3.5	106
1972	15.3	20.9	3.7	120
1973	23.2	21.0	4.0	135
1974	48.0	21.3	5.7	148
1975	51.9	24.6	5.9	150
1976	58.3	22.8	5.9	163
1977	68.6	23.8	6.1	173
1978	73.3	25.7	5.6	183
1979	101.3	24.3	6.2	-
1980	141.2	25.3	7.0	-
1981	149.0	27.3	7.6	-
1982	145.6	29.9	7.9	-

Source: UNCTAD Handbook of International Trade and Development Statistics, Supplement 1976, 1977, 1980 and 1981, Monthly Bulletin of Statistics, July 1980, July 1982, May 1984, United Nations.

The rapid growth of DC's mutual trade (from 23.2 billion in 1973 to 145.6 billion dollars in 1982) can be primarily attributed to two factors: the rise in oil prices (betwen 1975 and 1978, DC's mutual oil sales rose from 25.9 to 43.8 billion dollars), as well as the increase in the exports of manufactures (the value of these sales during the same period rose from 10.2 to 25.3 billion dollars). Here we must note that the share of oil in the total trade among DC's in these years fell from 55.3% to 48.4%, while the share of manufactures rose from 21.3% to 28.0%. Together these two categories account for over 3/4 of total DC's mutual trade!

Manufactures are of vital importance to DC's mutual trade: if we exclude oil, they account for a good half of this trade; and what is even more important, these countries can place final industrial products more easily on each other's markets than is the case with their exports to developed countries (according to statistical data for 1960 and 1970 these products'

share in the mutual trade was double compared to the one in exporst to developed countries). Thus in 1980, for example, the DC's sold over 70% of their exports of nonelectrical machinery and transport equipment to each other. In view of the increasing difficulty encountered in placing industrial exports on the markets of the developed countries, this is of great assistance to the DC's efforts in the area of export diversification.

We can thus come to no valid conclusions with regard to the relative importance of mutual trade for the DC's unless we study the data on the proportion of their mutual exports and imports to their total exports and imports, by major product categories. On the import side these countries greatest self-reliance is on mutual oil deliveries (about 90%), while this ratio is considerably lower in the case of agricultural raw materials (around 40%), and food (around 30%), while in the case of manufactures it is only a litle over 10%. On the export side this situation is much more balanced; only in the case of manufactures these countries sell more than 30% of their total exports among themselves, while in other sectors this proportion is much more modest (between 20 and 26%).

Measures for encouraging mutual trade are primarily limited to conventional preferential treatment (based on reciprocal tariff concessions), while such modern instruments as: long-term trade agreements, financial and payments arrangements, setting up of joint (multinational) chambers of commerce and information centers, etc., are only now being introduced (for the present primarily within integration groupings). One of the factors which seriously impedes the promotion of DC's mutual trade is also the lack of appropriate infrastructural services: from transport facilities, forwarding agencies, insurance, banking, to marketing channels and institutions for marketing information.

Least is being done to encourage exchange with the least developed among the developing countries. Thus between 1970 and 1980 their participation (we have data for 23 countries) in the total DC's mutual trade fell steeply (in imports from 5.5% to 2.9% and exports from 4.1% to 1.5%).

5. The most common forms of financial and monetary cooperation among DC's are the following:

a) multilateral and bilateral clearing and payments arrangements;

b) systems of balance of payments support;

c) co-ordination of monetary policies, pooling of monetary reserves and establishment of joint monetary institutions;

d) the establishment of sub-regional and regional banks and development funds.

In some integration groupings (in particular in Latin America and Africa) payments agreements have proved to be an important instrument for the promotion of intraregional trade. Up to the present regional and subregional banks (perhaps with the exeption of the Interamerican Development Bank) are not yet an important source of finance for regional economic cooperation. There is still very little direct cooperation between the commercial banks of the developing countries.

Monetary cooperation was most higly developed in Africa but now - in the process of intensified economic decolonialization - this cooperation is undergoing a transformation, which is accompanied by friction and constraints. Balance of payments support measures are at present of a certain importance only in Latin America, while in other areas these are only now being established.

6. In recent years industrial cooperation has been the object of considerable attention. Here practice is quite varied, ranging from market sharing and joint investments to joint programming. Especially in Latin America the establishment of joint ventures of a bilateral and multilateral type is increasingly emerging as a practical instrument for achieving greater self-reliance (not only at the microeconomic level).

With some exceptions, in particular in Latin America and in parts of Asia, the developing countries have not, up to the present, succeeded in putting into effect any appreciable part of their programmes for industrial cooperation, in particular in the area of joint programming and the promotion and coordination of regional industrial development. This can be explained, on

the one hand by the great complexity of this form of cooperation and by unfavourable objective conditions. On the other hand, there are also subjective factors: the differences in regulating the position of foreign capital, and in many cases countries are not prepared to increase interdependence with other national economies in the region, non even in their own integration grouping.

In spite of all difficulties intra - Third World joint ventures are growing in number (a conservative estimate execeeds 2,000 ventures) and importance - in some cases these enterprises provide a major share of these countries' domestic production. Besides manufacturing they are being established in a number of services: transport, banking, engineering and consultancy. Besides the conventional motives, the investors (private and public) realize that their genuine or well adapted foreing technology can provide a great advantage when they are investing in other developing countries. Since the conditions, problems, and requirements are often very similar, or at least more comparable than in the North-South context.

7. Scientific and technical cooperation and cooperation among DC's in the field of information are still very modest. However, in recent years great attention has been focussed on these forms of cooperation. Many acitivities have been initiated, both on the subregional and bilateral, as well as on the regional and global level. They will probably produce important results, some in the short-term, but still more on a long-term basis.

8. Almost three quarters of the developing countries (about 80 countries in over 30 groupings) are involved in integration processes on the subregional, regional and interregional level. There are many differences between these processes, but it can be said for practically all of them, that at least for the present they have not yet made a significant contribution to more rapid domestic economic development in the integrating countries, while - in some cases more, and in some cases less - they have strenghtened the negotiating position of the integrating DC's vis-a-vis the developed world (e.g. ASEAN and the Andean Pact).

Irrespective of the actual and nominal differences between the individual groupings, the basic mechanism which is used, was and still remains the reciprocal granting of tariff concessions in mutual trade. Preferential treatment is almost exclusively limited to the tariff rates, while quantitative restrictions usually remain unchanged (or are even extended). With rare exceptions (eg. the East African Community and the Central American Common Market), tariff liberalization did not cover the majority of products, nor did it significantly decrease the average level of tarif rates. In some subaregional groupings there is some division of labour and joint planning of industrialization. However, in no case has this instrument been fully developed. There is a similar situation with regard to the harmonization of operation rules for national, regional and foreign investors investment (e.g. codes).

If we wish to make a short assessment of the results achieved in the DC's regional integration processes we have to recognize that, taken as a whole, these results fall short of the expectations of the countries concerned. And, on the basis of the proportion of intragrouping exports to the total exports of the integrating countries, we can ilustrate the low level of economic interdependence in the framework of the main integration groupings in the developing world (in 1979 they accounted for only 12.5% of total exports).

Although a direct comparison of the integration of the developed countries with the integrations of the developing countries is of very questionable validity, we must stress that the former - at least for a certain period - led to a regionalisation of foreign trade of its members (in EEC and CMEA more than 50% of the member-countries' trade is conducted within these two groupings), while up to the present there have been no such tendencies in the developing countries. The data available indicate a marked tendency in the opposite direction: in the period 1970-1976 the share of intragrouping exports for 10 main DC's integration groupings in the total DC's mutual exports fell from 30.7% to 20.0% (if we exclude oil, however, this share remained practically unchanged, that is, at he level of 43%).

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PECULIARITIES OF CONTEMPORARY SCIENCE IN DEVELOPING COUNTRIES

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The title of the essay needs clarification.Science is generally considered tp be the study of matter in all its diverse forms; animate,inanimate,terrestrial or extra-terrestrial.This ongoing study is cumulative and has already resulted in an enormous number of facts and theories trying to knit them in comprehensible form.AS such its nature should be the same ,whether it originates in a developing or developed country.There cannot therefore be any peculiarities of science in developing countries.In this essay ,however,science is considered in a much broader sense so as to include in addition to facts and theories of science,also its practice and the practioners.Considered in this broader sense many peculiaritées of science in the developing countries emerge, which will be detailed in what follows.

The first point to be noted is the fact that science didnot originate in any one of the developing countries,it was an implant. This fact has been known for a long time but has been explicitly stated by a historian of science George Bassala.He writes;
"Until fairly recent times,any region outside of westren Europe received modern science through direct contact with the West European country". On the mode of introduction of science outside West Europe Bassala observed ;"Through military conquest,colonization, imperial influence,commercial and political relations and missionary activity, the nations of western Europe were in a position to pass on their scientific heritage to the wider world."(1)

Due to its peculiar mode of introduction in the developing countries science was divorced of the profound philosophical a· social,political,cultural and economic envoirnment in which it was born,developed and spread, in western Europe.This had far reaching effects for the further development of science in developing countries.As I have detailed elsewhere(2), the rise of science in Europe was also accompanied by a profound transformation in the philosophical world outlook;from that of a Aristotelian-Thomistic cosmology of a closed,hierarchically ordered geocentric universe,with its emphasis on the ephemeral, transitory nature of life on the corrupt,vile and base earth, governed by divine will and laws,discoverable only through introspection,deep meditation and contemplative speculation to that o. an open,infinite,unbounded, heliocentric universe of Copernicus,Kepler,Brahe and Bruno,governed by well-defined

laws,discoverable only through painstaking,well-conducted repeated observations and generalizations based thereon.The emphasis also shifted to the earth,earthly life and to man.Scholasticism of the middle ages gave way to empiricism and inductivism. Through scientists and philosophers like Galileo,Descartes,Locke and scientific bodies like the Royal Society (1642-),Science became EXPERIMENTAL-MATHEMATICAL.

This change of out-look can be summed up as follows.At the end of 15th century,educated people in Western Europe beleived themselves to be living in a static earth-centred hierarchical universe completely at the mercy of natural forces,continually menaced by demons and witches,against whome they were totally helpless.Two hundred years later ,they thought of themselves as living in a small planet circling round the sun,whose motion they understood. Further they thought,that the world around them followed well-defined laws,which could be discovered by experiments and deductive reasoning, and that it could be mastered and controlled.(3) Armed with this newly won confidence in themselves and their scientific method,the Europeans marched on not only to conquer and dominate their immediate environment but also to conquer and dominate other parts of the world.The rest is known and described in history books.

Because of its peculiar history in developing countries ,science there,is practiced in an environment which,from philosophical and cultural point of view,is predominantly prescientific.As a result, science in these countries continues to remain an activity which is consideredeither Alien or at the most marginal to domonant cultures.This is most clearly reflected in the extremely small size of scientific communities in the developing countries.

Underdevelopment of Science in Developing Countries:Some Statistical Indicators:

Although almost two-third of the world population of 4.5(4) billion lives in the developing countries,just over ten percent of the world total of 3,756,100 Research and development (R & D) scientists and engineers(s & e) work in developing countries.

The share of Africa is only 0.4 percent(population percent of the world total),for the Arab States only 0.9 percent,for the Latin American only 1.8 percent (population percent of the world population).(5)

Locked at from another point of view;the number of R&D ,s &e per million of population is only 125 in developing countries, varying from 52 in Africa, 287 in Latin America,252 in Asia.(6) Comparable figures for the developed countries is 2954 , varying from a high 5172 for the U.S.S.R, 2875 for U.S.A 2936 for Japan, 2479 for Poland , 1549 for U.K and to a low 824 for Italy (7) .

If one compares the expenditures on R &D by various countries and regions unsatisfactory situation of science in developing countries becomes more transparent,During the year 1980,the developing countries though possessing 10.6 percent of working R & D,S & E [illegible] spent only 6 percent of the world total expenditure of US $ 207 801 million . African region (excluding Arab countries and South Africa) having 0.4 percent of the world R & D,s & e spent only 0.3 percent of the world expenditure on R & D.Corresponding figures for Asia (excluding Japan) are 18.5 and 14.8; for Latin America 1.8 and 1.4. For comparison North America having only 18.5 percent of R & D s & e spent in 1980 , 32.5 percent of the world expenditure on R & D.The developing countries are thus not spending enough on their scientists and engineers engaged in R & D.(5)

Although the Gross National Products (GNP) of the developing countries are much lower in comparison to those of the developed countries, their expenditure on R&D as percentage of their GNP are even lower. Thus developing countries ,in 1980 spent on the average only 0.43 percent of their GNP on R&D compared to 2.24 percent for the developed countries. Even here the averages hide great variations among different regions and countries. For Africa it is lowest at 0.36 percent,highest for Asia, 1.18,Latin America spending only 0.53 percent of her GNP on R&D.(6)

From the above ,it is obvious that developing countries are lagging far behind the developed countries as far as their committment of human and financial resources for R&D is concerned.

Low level of Scientific Research

Insufficient importance to science is reflected in the low level of scientific research in developing countries in general [illegible] a .According to an estimate based on the analysis of publications emanating from the laboratories and universities in developing countries listed in CURRENT CONTENTS and in WHO IS PUBLISHING IN SCIENCE.About ten thousand research papers were published by scientists from developing, countries working within the developing countries, according to Current Contents. Of these 952 were from Africa region, 2611 from American region and 6053 from the Asian region India alone contributed 5089.(8)

According to WISPIS the corresponding numbers are larger,as it includes larger number of journals ,however,18229 scientific publications originated from developing countries in 1977.The regional contributions from Asian,African and Latin American were 13,977 (Indian contribution alone was 8802),420, and 3832 respectively.With the exception of India,Brazil,Argentina, Mexico,Egypt and Nigeria most other countries in the developing world produced scientific publications whose number remained in two figures.Only twenty developing countries produced fifty or more research publications.On the average there were, only 3.8 publication per million of population per year from the developing countries.(8)

Scientific journals from developing countries devoted to publishing research papers are few and only about one hundred and fifty are of reasonable quality with regular periodicity and wide circulation.There is a heavy bias in favour of life sciences as almost two out of every three papers are in life sciences.[7]

Employment of R&D Scientists and Engineers

In the developed countries most of the R&D scientists and engineers are employed by universities,laboratories or by industries. In U.S.A for example, of the 660,700 scientists and engineers engaged in R&D,in 1981,470,200 or 71.2 percent of the total were employed in the productive sector,96000 (14% of the total), were employed in higher education and about the same percentage of the total in general services.[9]Case for the U.S.S.R has been analysed by Notting and Feshbach in the U.S. journal SCIENCE, they concluded that 51.8 percent of all scientific workers were employed by the industries and the rest are engaged in the fundamental and R&D related work in the universities and Academies".[10] In comparison, most developing countries tend to employ the overwhelming numbers of their scientists and engineers in non-productive sectors,employing most in higher education or general service sectors.For example in sector in 1980, of 9,500 scientists and engineers working in the R&D sector,only 1,700 were employed in the productive sector while 5,200 and 2,600 that is,17.9%,54.7% and 27.4% were engaged in higher education and the general service sectors respectively.[11]In COLOMBIA,of the total 3,404 scientists and engineers ,in 1978, only 50 (1.5%) were employed in the productive sector while the rest were in higher education and general service sectors.In Sudan of the 3,806 only 967 (25.4%) were innthe productive sector.[9] In general,this situation is characteristic of almost all of the developing countries.While the developed countries employ over half of their R&D scientists and engineers for developing new products,the developing countries tend to deploy most of their meagre R&D manpower in non-productive sector.

Utilization of Potential S&E in R&D and their support

The developing countries donot make adequate use of their available scientific manpower for R&D purpose.In India,of the potential 1,115,000 scientists and engineers in 1978, only 56,527 or 5 percent were employed in R&D. This percentage as high as 23.4 for German Democratic Republic,20.9 % for the U.S.A.,11.2 % for U.S.S.R.,9.7 % for Australia.Among the developing Countries,the percentage was two for Argentina and 1.7[12] for South Korea.In general the developing countries are able to deploy only a very small percentage of their apotential scientific manpower for R&D purposes.

Even when the developing countries are abele to deploy part of their scientific manpower for R&D purpose,they are unable to

back them up with sufficent resources.In general the developed countries spent in 1980 58,169 US$ on each R&D scientist compared to 31,294 US$ which was spent by the developing countries on each one of their R&D scientist.[13]But it hides great variations; India,in 1978 spent only US$ 6,813 per R&D scientist,while Pakistan spent only slightly more than four thousand US $ on each of her R&D scientist, in the same year.[14]

Future Trends in R&D personnel and R&D expenditures

If one analyses the trends in the R&D personnel development and expenditure on R&D in various countries,another unsatisfactory feature of the developing countries emerges.In figure 5 ,these trends are displayed. As a can be seen,the number of R&D scientists and engineers is increasing very rapidly in the developed countries, while in the developing countries the increase is very slow.The expenditure on R&D in developed countries is however rising very very rapidly.In comparison,in the developing countries the rise from a already very small base is very slow.[15]

All the facts given above go on to demonstrate that although most people in developing countries come in contact with science through its applications in products like radio,television,telephones,tele-graph,electricity,railways,cars and other transport vehicles,aeroplanes,medicines,chemical fertilizers and pesticides, tractors and tube-wells and thousand others,science and scientific research are either totally alien or at the most marginal to indigenous cultures.Scientists are either not organised or at the most loosely organised in professional bodies.There is either no scientific research output or if there is any ,it is of insufficient quantity and quality.

From the discussion above,the following peculiarities of contemporary science in developing countries emerge:

1.Developing do not in general possess self-sustaining,viable and well organised communities of scientists and engineers.

2. Even when scientists are available ,far fewer of them are deployed for R&D purpose.

3. Even those who are employed for R&D purpose,the greater majority is usually employed in non-productive sectors.Those employed are not backed with adequate resources.

4. Developing countries in general and African countries in particular are investing far too little of their human and financial resources to create,maintain and develop their scientific capabilities.

5. Many of the developing countries (ninty)[16] have far too small a population base to create,maintain and develop an independent,viable scientific and technological system.
6. In all of the developing countries science is practiced in an environment which is pre-dominantly pre-scientific and pre-industrial
7. In most developing countries expenditure on science seem to take the character of consumption rather than investment as is the case in developed countries.[17]

Steps To Overcome the Underdevelopment of Science

Anumber of steps can be suggested to overcome the underdevelopment of science in the developing countries so that science can take its rightful role as one of the most important agents of innovation and development. These are:

1. Governments in developing countries should be persuaded to adopt social and cultural policies ,which promote,objective, rational and scientific thinking.
2. Scienc policy should be made an integral part of the general economic development planning.
3. Detailed studies should be undertaken by each developing country to assess the strengths and weaknesses of her scientific and technological capabilities in all of its multifaceted aspects.Commitment then should be undertaken for adequate human and financial resources to remedy any shortcomings and to exploit fully the existing scientific potential.
4. Extensive schemes should be undertaken for the popularization and cultivation of science through all available media.
5. All efforts on bilateral,multilateral and international levels should be made in order to overcome the underdevelopment of science in the developing countries in general and in the African region in particular.
6. Expenditure on science should be greatly increased in all of the developing countries in general and in African countries in particular.
7. Full utilization of existing scientific manpower should be attempted.
8. Research activities in universities should be greatly expanded and backed with adequate resources,human as well as financial.
9. In view of the small population and resource base of over ninty developing countries,regional centres for science should be established either through the UN agencies or through other bodies. Scientifically more advanced developing countries like India,Brazil and Argentina could be seats for such centres. International Centre for Theoretical Physics inItaly and Latin American Centre in Cracas are already well established examples ,which should be multiplied mani-fold and in all branches of science.

10. A serious attempt should be made to understand in an objective and scientific manner the possible causes for the underdevelopment of science in the developing countries.

In a forthcoming study we will attempt to do just that.[18]

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CONTENTS

Introduction

The desire to escape into the myth of a golden age is one of the reasons of the prevalent anti-science attitude. There was never a golden age. It is easy to forget that the problem of keeping everyone fed, clothed, and in reasonable health cannot be solved without science.

People of widely different political convictions have a biased view about science. By distinguishing between the physical world and the spiritual world, we have, Koestler suggests, brought about a unique increase in our physical power and a decline in our moral or spiritual awareness. Brecht is concerned with the subjugation of scientific research to the political dictates. Advancement of science and technology did not have only negative effect. Shooting missiles across the continents is not the only outcome of the technical development. Since the scientific community is a part of the society, there is no reason why it should be more vulnerable to political pressure than any other group of a democratic society.

Science is going to stay with us. We must learn to utilize its benefits. An environment with a free flow of information is most suitable for coming to terms with science and technology. In a society where the interested persons and groups can get the information they want, an industrial policy could be developed, which would select useful innovation from those which merely contribute to more profit, more working hours, and more consumption and power for an elite.

Many problems we face are not scientific and will have no scientific solution. But scientists can contribute to the solution of these problems. Modern technology can increase the linkage of a great number of people to the information system. This will reduce the chances of manipulation and exploitation of the less privileged by an elite.

The paper is organized as follows: in section 1 the most important resource, energy, is discussed. In section 2, the connection between useful energy and information is established. All energetic processes in the biosphere are driven by solar energy The origin of sunlight is the nuclear reactor at the core of the sun. The origin of nuclear fuel is discussed in section 3. Solar energy made life possible and in the course of evolution organized societies evolved - this aspect is touched upon in section 4. In modern societies technical development is connected with more speed. This requires more energy. The consumption, in terms of exergy, of the rich has been increasing rapidly. This is the topic of section 5. In section 6 it is claimed that in many cases technological unemployment results from not implementing new technologies. The relationship between technology, development and environment is discussed in section 7. Some general policies on research and resource management are discussed in the last section.

Energy

Energy is omnipresent. There is very little matter in the intergalactic space but radiant energy is everywhere in the Universe. In 1965 this microwave radiation was detected. If energy is everywhere in the Universe, why do we talk about "energy crisis"? Clearly if a resource is not scarce, there cannot be any crisis relating to it. Let us take another example. The amount of energy received by the earth from the sun is 175,000 TW (1 TW = 1000 Gigwatt = 1 million Megawatt). Total energy now used for all human activities is less than 10 TW.

After ten years of discussion on "energy crisis" many people know that the crisis is about useful energy (which we call exergy) - the energy that can be used to do work. What work? Transportation, production of consumer goods, space heating, construction etc. Solar insolation can be utilized to generate electricity and perform work.

There is abundant solar energy. What is scarce is technology. Technology is not only machines. Technology is also knowledge to run these machines, to organize the distribution of consumer goods and services. Energy and for that matter no resource is scarce. It is knowledge that is scarce. It is also the inappropriat application of technology which creates an artificial scarcity of resources. The presence of poverty in the midst of plenty is a clear manifestation of our intellectual failure.

Table 1 here

The goal of technical progress had been to eliminate suffering, unnecessary death, inequality of income and wealth. This goal

has been reached to some extent in the industrialized countries. Looking at table 1 you will see that energy use is directly correlated to all indicators of well-being. Energy is needed to build schools, to run hospitals, to control indoor temperature, to feed people, to operate particle accelarators. Overall energy use will not decrease with technical progess. Processes become energy efficient only if the price in monetary units of energy increases. But new products and new people come in the market and more is produced or supplied.

Energy is important and it is not scarce. Life would not evolve if the most important prerequisite for it would be scarce. The earth intercepts only a negligible portion of total energy emitted by the sun. Yet this is already 2200 times more than what would be necessary to supply 8 billion people with 10 KW of energy per capita.

In the physical resource theory group of Göteborg we developed a model in which we took energy to be plenty. In economic terms we can set its price to be zero. We set an upper limit to the amount of available energy. This upper limit might exist for a human society. It may exist due to regulation for the preservation of certain species of landscapes. A society might value things which do not lead to more consumption, more airfields, fast motor-cars, a life free of risks of all kinds.

But one thing is certain. Below a certain level of per capita energy use certain elementary services cannot be provided - basic hygiene, sanitation, reasonable housing, food and clothing. Energy is the most important input to achieve these goals. It is of course not the only one. Our willingness to provide everyone with at least the above mentioned amenities is important.

If this will exists the next thing is the proper organization of an economy and a society. This indicates that these problems are outside the realms of science. But science and technology

makes achieving these goals easier. Science and technology is knowledge. The other inputs are energy and material. From these everything else can be produced. If energy and knowledge are so important, the question arises whether they are also interrelated. The answer is: Yes, they are.

To understand this we have to know the nature of energy and knowledge from a fundamental point of view. Knowledge can be described as organized information. That technology (organized information) can be used to improve energy efficiency is an example of this interrelatedness.

Another entity connected with energy and information is time. This is a consequence of the laws of thermodynamics. The faster a process works the more exergy is dissipated. Maximum efficiency is possible only in reversible thermodynamic processes. But reversible processes are infinitely slow. Human beings with a finite span of life must work with finite speed. Modern societies substitute exergy for time.

2. Exergy and information

Three fundamental resources - energy, material and information - are necessary for the creation, organization and preservation of ordered structures. A human society is an ordered structure which functions by using information and by transforming and exchanging resources, goods and services.

The first law of thermodynamics says that energy is conserved. It does not imply that all structures, once realized, will last forever. The maintenance of a structure requires the dissipation of energy and material - the degradation of high quality energy and material into low quality energy and material.

The second law of thermodynamics states that the quality of energy is <u>not</u> conserved. Quality of energy is determined by the amount of mechanical work that can be extracted from a given amount of energy. The useful energy or the energy available to do work is called exergy [1]. Exergy is energy in ordered form. The exergy of a system is zero when its energy is maximally distributed, i.e. when disorder has reached its maximum and the system is said to be in thermodynamic equilibrium. Dissipation of energy and material is best described as consumption of exergy. It is a consequence of the second law of thermodynamics that exergy must be consumed in all processes that are to proceed at a non-zero speed.

The change in entropy in a system can be written as [2]:

$$dS = - (dE + dW)/T_0 \qquad (1)$$

where E is the exergy given by

$$E = S(T-T_0) - V(P-P_0) + \sum_i N_i (\mu_i - \mu_{io})$$

W is the amount of mechanical work that can be extracted from the system. T, P and μ_i are the intensive parameters of the

system - temperature, pressure and chemical potential. The subscripted symbols correspond to their values in equilibrium V, S and N_i are the extensive parameters - volume, entropy and numbers of different molecules.

Eq. (2) shows that the exergy vanishes at equilibrium, i.e. when $T = T_0$, $P = P_0$ and $\mu_i = \mu_{i0}$. During the process through which equilibrium is attained, the exergy consumed is E. If the total entropy increase is S and the work extracted is W, then the integrated form of (1) is

$$S = (E-W)/T_0 \tag{3}$$

or

$$W = E - T_0 S$$

Only for reversible processes is S = 0, otherwise it is positive so that W < E, i.e. exergy is the maximum amount of work that can be extracted from the system.

If we assume that the system evolves towards equilibrium without doing any work the entropy of the system changes from S to S_{eq} and the integration of (1) will give

$$S_{eq} - S = E/T_0 \tag{4}$$

The left hand side of the above equation is negentropy. Exergy is thus temperature times negentropy.

Negentropy is information capacity [3]. A structured system has more information in it than a disordered system. Exergy and negentropy are related in that exergy can be used to create ordered structures and new information [4]. Let us consider solar radiation reaching the earth. It contains very little information. Since sunlight is hotter than the earth's surface, its exergy content is high (cf. eq. (2)). This exergy makes the creation, preservation, organization and orderliness of various terrestrial dissipative structures possible.

3. Creation of Nuclear Exergy

According to the standard theory, the early Universe, due to high density was in thermal equilibrium within one hundredth of a second after the Big Bang. Thus the Universe had already reached the state of heat death, its exergy was zero: But when we look at the sky we see examples of extremely ordered systems consuming high amount of exergy - the stars.

How could order be restored in a totally unordered Universe? Expansion helped the Universe to come out of the stalemate. Due to the expansion, the conditions for local equilibrium changed with changing temperature and pressure. The universe expanded so fast that the mechanisms for sustaining equilibrium could not keep pace with the expansion. Thus order and disorder can grow simultaneously in the expanding universe. This does not violate the second law of thermodynamics. In an expanding Universe the entropy S increases but its maximum attainable entropy S_{max} may increase faster due to the expansion which increases disequilibrium.

The source of starlight is the nuclear reactor at the core of the star where mainly hydrogen is burnt into helium. Why is the Universe composed mainly of hydrogen? To understand the overwhelming abundance of hydrogen in the Universe we have to go back to the instant 0.01 seconds after the Big Bang.

Temperature of the Universe at 0.01 seconds after the Big Bang was 10^{11} K: At this temperature the electron and its antiparticle positron, and neutrino and antineutrino can keep protons and neutrons in equilibrium. This means that we cannot distinguish between protons and neutrons. Since exergy is contrast, we have no nuclear exergy. Reactions of the following types occur at this temperature.

Antineutrino + proton $\rightleftarrows$ positron + neutron
Electron + proton $\rightleftarrows$ neutrino + neutron

In thermodynamic equilibrium the relative abundance of two types of particles is determined by their mass and is given by the Boltzmann's statistical theorem:

$$(\#\text{neutrons}/\#\text{protons}) = \exp\left[(m_p - m_n)c^2/kT\right]$$

The heavier neutron is thus less bountiful to start with. At a slightly lower temperature, it is easier for the heavier neutron to turn into proton, so that the reactions going from right to left are more favourable and thus the neutron proton ratio drecreases further. About 14s after the Big Bang the temperature has dropped so far that the radiation has no more energy to produce electron positron pairs. The conversion of protons into neutrons requires the presence of electron positron pairs. So neutrons and protons at this point can be distinguished and the <u>nuclear exergy comes into existence</u>.

It started with 24% neutrons and 76 % protons. At this point the nuclear exergy is tied to the neutrons which can decay into proton, electron and antineutrino, thereby releasing 1.294 MeV per neutron. As time goes on the Universe becomes cool enough for various stable nuclei to form. If the Universe had been expanding slowly, it would have happened. But the Universe expanded extremely rapidly. In this condition nuclei can only be formed in a series of two particle reactions. And here was the lucky coincidence which prevented the consumption of all nuclear exergy. The deuterium nucleus - half way toward helium - is extremely looseley bound. They were torn apart by the energetic radiation as soon as they were formed, so that the heavier nuclei do not have a chance to form. Nuclear exergy has been trapped in the form of protons. Only about one fourth of the baryonic matter has been synthesized into helium.

The era under consideration is characterized by high temperature but the density of matter is somewhat less than that of air. We consider the nucleon gas as a non-relativistic Maxwell-Boltzmann gas. The exergy per nucleon is given by

$$E = \sum P_i \frac{kT}{A_i} \ln \frac{P_i}{P_i^{(0)}} \qquad (5)$$

where i lables states and P_i is the actual probability distribution for one nucleon, and $P_i^{(0)}$ is the probability distribution

for one nucleon at thermodynamic equilibrium.

In a simplified model [6] we consider that a nucleon may either be a free proton or a free neutron or it may be bound in ^4He or ^{56}Fe. ^4He was formed abundantly during the cosmic nucleosynthesis and ^{56}Fe is a natural candidate by virtue of its being the most tightly bound atomic nucleus. At low temperatures the statistical factors depend sensitively on the energy levels. This leads to an all-or-none situation. Below 2×10^9K, ^{56}Fe totally fixes the normalization of the $P_i^{(0)}$. The inclusion of other nuclei would not change the result appreciably.

The equilibrium distribution of the nucleons over the four nuclear states under consideration is

$$P_i^{(0)} = x r \left(\frac{mc^2}{kT}\right)^{3/2} g_i A_i^{5/2} \exp\left[-A_i\left(\mu(T) - b_i\right)/kT\right] \qquad (6)$$

where g_i is the spin multiplicity of the state i, A_i its mass number and b_i is the average binding energy per nucleon (relative to a free proton). Table 2 gives A_i, g_i and b_i. The ratio of photon to nucleon, r, in the Universe is taken to be 10^9, the nucleon mass m and the constant is given by

$$m = 0.24\, m_n + 0.76\, m_p = 938.6 \text{ MeV}/c^2 \qquad (7)$$

$$x = \frac{\sqrt{2\pi}}{8\zeta(3)} = 0.351 \qquad (8)$$

The chemical potential $\mu(T)$ in eq. (6) is fixed by the overall normalization condition

$$\sum P_i^{(0)} = 1$$

The actual probability distribution and other characteristics of the four nuclear states are given in Table 2.

For simplicity we assume that all helium was synthesized at $T = T_0 = 10^9$K and $\gamma(T_0) = 13.5$. $\gamma(T)$ has to be calculated numerically. Eqs. (5) and (6) and the data in Table 2 gives

the exergy per nucleon before and after the helium synthesis as

$$E(T) = \mu(T) + |b_2|\gamma(T) - kT \ln \frac{2xr\left(\frac{mc^2}{kT}\right)^{3/2}}{\gamma(T)^{\gamma(T)}\left(1-\gamma(T)\right)^{1-\gamma(T)}} \quad (9)$$

$$T > T_0$$

$$E(T) = \mu(T) - 2\gamma_0 b_3 - kT \ln \frac{2\left[xr\left(\frac{mc^2}{kT}\right)^{3/2}\right]^{1-\frac{3}{2}\gamma_0}}{\left(1-2\gamma_0\right)^{1-2\gamma_0}\ \gamma_0^{\frac{1}{2}\gamma_0}} \quad (10)$$

$$T < T_0$$

The creation of nuclear exergy is plotted in fig. 1.

Fig. 1 here

After about 700,000 years the Universe was cool enough for the atoms to be formed, i.e. electrons could settle down on the atomic nuclei. If the hydrogen atoms were uniformly distributed the nuclear exergy would not be available to do work. In the cosmic order gravity plays the most important role. Gravitational force is experienced by all particles of the Universe. In time gravity clumped matter into protostars and protogalaxies. The stars burn protons into heavier elements and release energy and this makes life possible.

Gravity is also in itself a source of exergy. After hydrogen and helium has been burnt in a star, further gravitational contraction with its consequent heating takes place and heavier nuclei are formed in the stars until the end product is iron. If the star has a small mass it would end up as a white dwarf. If the star is heavy, the gravitational attraction would be so high that the protons will capture electrons to become neutrons. Enormous temperature and pressure develop, allowing all sorts of nuclear reactions that cannot otherwise occur and heavier nuclei are formed. Pulsars are the rest of such neutron stars which became supernovae and blew out matter in the interstellar space. Many proton rich nuclei can be produced only through (p,γ) reactions, since the coulomb barrier in such a reaction is very high they can take place only in a highly energetic situation, as in a supernova explosion. The fact that our solar system contains heavy elements indicates that it is made of material which was blown out of stars, and there is evidence that it has gone through this star-interstellar dust-star cycle more than once.

The exergy per nucleon in a star thus is a function of its mass. At low mass the stars ends up as white dwarf, in this case the nuclear exergy is augmented by a few keV per nucleon of gravitational exergy. For neutron stars the nuclear-gravitational exergy per nucleon is of the order of 40 MeV. For systems large enough to have a black hole as its final state the exergy per nucleon may be around 100 MeV/nucleon.

Modern elementary particle physics suggests that the proton is unstable. In this case matter itself represents a form of exergy with a very long half life ($\sim 10^{31}$ years). But if the Universe is open, even this exergy will also be consumed in nuclear decay and the Universe will consist of very thinly spread electrons and positrons (so that they cannot annihilate each other), photons, neutrinos and gravitons.

Exergy is a measure of contrast. This contrast can be internal to the system (e.g. proton decay) or against an external environment (e.g. the formation of the iron nuclei). Iron is the most tightly bound nucleus. Energy is thus released when nuclei heavier than iron are torn apart (fission) and lighter than iron nuclei are fused together (fusion). Stellar nucleosynthesis uses the exergy trapped in the protons at the beginning of the Universe and the gravitational exergy of supernovae are trapped in the actinides and in other proton-rich nuclei (e.g. the tin isotopes with $A<116$).

4. Emergence of Organized Societies

The ex[illegible] that was trapped in the protons a few minutes after the Bi[illegible] powers the Sun. Our planet is a resource converting system. [illegible]e water cycle and other cycles of the earth use the sun as [illegible] boiler and the space as a cooler to extract work.

Without the solar radiation, the earth would have cooled down with a continuous flow of heat from the interior of the planet into the outer space. Neither the solar radiation, nor the earth's surface, if considered in isolation,has much negentropy. It is the contrast between the two interacting systems that makes the combined system rich in exergy or negentropy. Life would not emerge on the earth without the influx of solar radiation. Information in the genetic material of the primeval life grew into a rich and complex biosphere in the course of evolution. Out of the exergy or information capacity of the solar radiation, new information is generated and existing information and structures are maintained.

From equation (2) it is obvious that a resource is characterized by its deviation from equilibrium. It is a law of nature that systems tend towards thermodynamic equilibrium. Spontaneous processes drawing a resource into equilibrium with its environment destroy that resource. For this reason all resources are to some extent scarce. Exergy and negentropy both measure the deviation of a resource from equilibrium. Either of them can be used as an overall resource measure. It is relevant to restrict negentropy to the physical level and use the term 'information' for knowledge. Exergy can be used to measure both useful energy and material which is not in equilibrium with its environment [4].

More than ten thousand years ago humanity invented agriculture and started to abandon gathering/hunting as the main activities to bring resources in the society. With agriculture human societies moved away from a close balance with their natural environment into a situation where a considerable input of labour, organization and resources were necessary to keep their land

away from such a balance. With time these inputs have increased in organized societies. One of the results of this development is inequality in the control and use of resources. Two hundred and fifty years ago Richard Cantillon observed that [7]:

> "If the proprietors of Land, who live in the Country go to reside in the Cities far away from their Land, Horses must be fed for the transport into the City both of their food and that of all the Domestic Servants, Mechanics and others, whom their residence in the City attracts thither.
>
> The carriage of Wine from Burgundy to Paris often costs more than the Wine itself costs in Burgundy; and consequently the Land employed for the upkeep of the cart horses and those who look after them is more considerable than the land which produces the Wine and supports those who have taken part in its production. The more Horses there are in a State the less food will remain for the People."

But unequal distribution and consumption started long ago. About three thousand years ago an empire was organized as shown in an adapted version of Herrman's [8] representation of an oriental society.

Fig 2 here

Fig. 2 shows that power increases in the vertical direction and that it is directly correlated with the use of information by different groups. Information is the resource par excellence. From the earliest period the individuals and groups followed strategies which would bring them nearer to the centre of information generation and transmission. Possession of information and the ability to manipulate it is power. Priests were almost always more powerful than mere kings. Where the offices of the highest executive and the chief priest were united (the divine king) the power reached its maximum.

5. Technological Development: Knowledge is Power

Exergy can be used to generate new information and information can be used to lower the exergy required to perform certain tasks. Technical development means that increased output can be obtained from a fixed amount of labour and resources, or alternatively that the same level of output requires less labour and resources. When technical development is embodied in new machines, it is called embodied technical progress. Disembodied technical progress is the increase in efficiency because of organizational and institutional changes.

In short, technical development increases efficiency thereby giving people more voluntary leisure. The upper class in a society wishes to remain near the centre of information generation. The power of the upper class lies in the fact that they can manipulate information. They also ensure that the world is interpreted as they wish. To retain this capacity in the face of a mass of new information they need to control their use of time. If they are tied to high frequency (repetitive) jobs like household chores or factory work they lose their manipulative power. The upper class for this reason always have occupations which Douglas and Isherwood [9] call low frequency activities. This makes it possible for them to be available at short notice for encounter with other powerful persons and groups. Accordingly a large part of their consumption is information based consumption. This class could as well be called the <u>information class</u>. A person in this class preferentially possesses and consumes commodities and uses services which will increase his ability to interact with the information system as a whole.

The concept of "availability for encounter with persons and groups of influence" can be illustrated by the following example. When Bismarck was playing a very important role in Europe, he spent a considerable amount of time feasting and hunting with his peers. His power base was the German aristocracy; he had to be personally available to them. A German Chancellor nowadays can hardly indulge in such activities. He has to be available to

the parliament, his party, trade unionists, other politicians, the media, industrial magnates, in Brussels and so forth. The German Chancellor uses an airforce jet to cover distances of the order of a few hundred kilometers. To retain his office he must be available to as many people, groups and places of influence as possible. His consumption in terms of exergy is a few hundred times more than the more powerful Prince Otto von Bismarck.

Technological development thus increases the personal availability and enhances the consumption of the information class. This concept can be modelled with the following qualitative relationship

$$\text{Availability} = A\left[1 - \exp\left(-\frac{\alpha I + \beta T}{E}\right)\right]E \qquad (11)$$

Where A, α and β are constants, E is exergy and I and T denote the information component and the technological component of consumption. When the use of information and the level of technology is very low, availability is independent of the input of exergy, since in this limit eq. (11) reduces to

$$\text{Availability} = A\,(\alpha I + \beta T)$$

When, on the other hand, the level of technology and the use of information is very high per unit of used exergy, eq. (11) becomes

$$\text{Availability} = AE$$

i.e. availability in this case is directly proportional to the input of exergy.

Fig. 3 here

This is simply a qualitative way of showing that as technology develops availability increases. With the help of new technology more information can be processed which in turn increases the availability yet more. This is illustrated by a modified version of Spreng's [10] triad. Fig. 3 shows the well-known fact that people performing non-repititive tasks use more exergy and more

information. Speed is important for them, so they substitute exergy and information for time.

Technological development has resulted in more consumption for every one in the industrialized countries. But the consumption of the information class has increased disproportionately. Technological development makes it possible for them to be available at different places at ever increasing speed. Their consumption is mainly composed of university education, visits to concerts, dining with persons of influence, attending conferences, lecturing abroad, telephone calls, telex, computers, books and journals. People of the information class must let the less important persons know that they are busy and unavailable. This apparent unavailability is in fact their very high availability in their technologically expanded social interaction.

Technical development definitely increases the voluntary leisure of all classes in a society but the middle and lower classes do not preferentially demand or consume those technical gadgets which would increase their capacity to acquire more information or interpret information independently of the manipulators.

Douglas and Isherwood classify consumption in three categories
1) consumption of staples
2) technology based consumption
3) information based consumption

A commodity is called staple if it is needed for high frequency tasks, e.g. household appliances, motor car for a travelling salesman. Technology based consumption bundle is composed of goods that have been newly introduced in the market. People with higher income but not belonging to the information class tend to buy every new technical gadget that is introduced onto the market - e.g. colour television, video. The information class do not buy these goods immediately, if such goods neither increase their availability for encounter with powerful persons nor their capacity to acquire and manipulate information.

With this classification [illegible] luxuries and [illegible]

market, was a luxury item in the conventional sense, but now almost every household in the industrialized countries owns a television set. This is also the case with the refrigerator and vacuum cleaner. The acquisition of such goods is sometimes illustrated by the "spread of infection" model.

In this simple model, all households which are "susceptibles" end up buying the commodity. The interesting thing is that the "rate of infection" varies considerably for different goods in the same price category. The rate of spread of many new commodities and services in the same price category among different social classes cannot be explained by the budget-constraint alone.

Fig. 4 here

The technical gadgets needed for high frequency activity - refrigerator, vacuum cleaner - have been acquired by all households. Although the telephone was introduced more than a hundred years ago, still it has not infected everyone (fig. 4). Some people argue that technical limitations prevented the service from spreading faster. This can hardly be true. If a service or a commodity is demanded then the producers see to it that it is made available, apart from reducing prices by economies of scale, credit facilities are used to bring the commodity to the consumer.

People in the lower class did not need the telephone. Firstly because none of their friends and relatives had a telephone, secondly because they do not have control over their time. They perform high frequency tasks. They cannot choose to be available in a certain place at a certain time. But the people performing low frequency tasks need to cancel their appointments, make new appointments, be available at short notice in faraway places. They have to talk to their lawyers, their publishers, their agents, their acquaintances of influence in different countries. They need the telephone, so they have the telephone. Not so in the case of television. [illegible] right [illegible] beginning the middle income group owned [illegible] television [illegible] the information class. [illegible] information [illegible] information [illegible] e.g. books,

newspapers, radio etc.

Services and commodities supplied are oriented towards the needs of the information class. Before the advent of the efficient high speed electronic communication era, mail was delivered three times a day. At that time the Cambridge dons and the business community used the postal service as the main channel of communication. One could get a reply to a letter sent to London from Cambridge on the same day. Now they have other channels of communication so that the letters are delivered only once a day. In Sweden letters are not delivered at the week-ends, registered letters have to be collected from the post office and the telegrams are slower than express letters. If the upper class does not demand or consume a service, the service deteriorates.

6. Informational Aspect of Economic Disequlibrium

Information is neutral but its use is not. Non-use of information is also not neutral. Gerhard Mensch [12] , in a book of remarkable scholarship, shows that the long waves of development observed in the capitalist economies result from the non-use of information.

Capitalism, according to Schumpeter [13] , cannot be a stationary affair. From its very nature, capitalism is evolutionary. The main forces keeping capitalism in motion are the introduction of new consumer goods and the mass production of already existing goods. This requires innovation or advancement in technology - both embodied and disembodied.

Mensch classifies innovation in three categories:

1) Basic Innovation
2) Improvement Innovation
3) Product Differentiation

Basic innovation is the last stage of a series of events - starting from a scientific invention - at which a new technique is used in the production process or a new product is introduced to the market. Basic innovations open up new fields of activity and create new jobs for a number of people. Non-technical basic innovation generates new cultural activity, new types of public administration and novel social services.

Improvement innovation in one industrial sector introduces products to the market which are better in quality and reliability, inflict less damage to the environment and require less raw material and human labour for their production. It remains a seller's market because consumers want to buy qualitatively better products. But then comes a stage when a product cannot be improved, at least not at a price acceptable to the normal consumer. This is a consequence of large scale production processes, which are difficult to modify. The elasticity of substitution being very low [14], they have to operate with obsolete technology or continue to produce goods for which the demand has declined.

At this stage the producers indulge in an activity classified by Mensch as product differentiation. Something is packed better, given a shiny colour. But this does not help. The seller's market has become a buyer's market. The market is saturated.

It is for this reason that from the industrial revolution onwards, the capitalist economies developed through cycles of prosperity, recession, depression, and recovery. Kondratiev [15] first observed these cycles. These cycles have a duration of approximately fifty years. They are given in Table 3.

Table 3 here

I have named the cycles according to the main source of impulse of that cycle. The fourth cycle is the Control-Kondratiev since in this cycle we produce better motor vehicles, better aircrafts, computers and spacecrafts by learning to control rather complex systems. The fifth Kondratiev will definitely be a cycle of versatile automatic systems and biotechnology - a revolution in understanding the modes of information transfer and information processing in living and non-living systems.

Modifications in the patent system could make depressions less acute. The patent system was introduced by the Doges of Venice in 1474. During the Renaissance when the manufacture was handicraft, the inventor and the innovator was the same person. Nowadays innovation is a highly organized activity comprising governmental, industrial and academic research and development.

Mensch shows that the number of inventions per unit time changes smoothly whereas the basic innovations come in bunches. The large scale production processes lead to high inertia in firms, which do not change their mode of production unless they are forced to do so. To avoid improvement innovation, they not only do not use their own patents, they also buy other patents to prevent them being used. Non-use of information results in higher cost and lower quality of consumer goods. The production sector delays the implementation of new technology till the crisis has become so critical that anything that generates more profit or more employment is introduced irrespective of its long-term effect.

7. Technology and Environment

Industrialized societies are now faced with the problem of structural unemployment. There is huge unemployment and malnutrition in the poor countries. From these many people draw the conclusion that the world is overpopulated. Only about twenty-five years ago industrialized countries invited workers from the poor countries to join their labour force to produce surplus.

The concept of 'carrying capacity' cannot be applied to the Homo Sapiens. Technolgical Man has unlimited capability to increase human welfare.

Overpopulation is not a cause of poverty. Rich countries have social security systems. Rich people can also save for old age. This makes them less dependent on their children. If the children transfer mor income to their parents than they received, people will have more children. This is a rational economic decision. Robert McNamara, in a lecture at MIT, cited a forty country survey which showed that an increase of $ 10 per capita income for the poorest 60 percent led a fertility decline more than twice as rapid as a $ 10 increase in the national average income.

Neomalthusian conservationists are worried about overpopulation and at the same time they are against economic growth and the rapid industrialisation of the poor countries. John Kenneth Galbraith describes the conservationist as a man who concerns himself with the beauties of nature in roughly inverse proportion to the number of people who can enjoy them. The size of the population is a problem. It has always been a problem. It is at least 12,000 years old. Rhys Carpenter [16] describes the race of hunters who lived in what today is France. There were a lot of animals - reindeer and bison - on which they fed. But nothing endures forever, and the happy hunting ground faded away with the melting ice. The new warmth turned scrub growth into forest; swamps and marshland replaced the open pastures. In search of the old way of life the animals and the hunters wandered across Russia into Siberia. But the hunters who stayed behind had to adapt themselves to less bountiful conditions— snaring, trapping and fishing. Artistic skill (cave painting)

disappeared; craftsmanship diminished. This was the first great cultural recession. All this continued for a relatively long period because the population was small. If there had been more people they would have invented agriculture earlier.

The real per capita income in Bangladesh has remained the same during the period 1950-77, although the population doubled during the same period. As the population increased, marginal land was brought under cultivation and the agricultural technology improved - new seeds, hybrid strains, fertilizers and an intensified use of natural resources. I doubt whether per capita national income would increase significantly if population had not increased. Poor people living at a mere subsistence level do not change their way of life on their own initiative. But it is a commendable feat for a poor and overwhelmingly illiterate people to have kept their per capita income constant when their number increased from 40.6 million to 81 million. Per capita income remained the same in spite of recurring floods and droughts, in spite of the frequent cyclones and tidal bores in the years 1958-70, in spite of a devastating war of independence, in spite of mismanagement of the economy by the politicians, the military and the bureaucrats.

Nature is not always kind to human beings. In vast areas of the developing world, water is the source not of life but of debilitating and often fatal diseases, such as malaria and bilharzia which alone claim an estimated 200 million each. In Africa some 20 million persons are afflicted with "river blindness" caused by a parasite which breeds in fast flowing rivers. If the water stands still it breeds malaria, if it flows it gives blindness. The only way to make life better is to use chemicals or other scientific techniques. The risk is very small that the whole ecosystem will be destroyed in the process of fighting death and misery, since:

> the ecosystems are not so precariously balanced that the extirpation of one species must act like the first domino.... Indeed it could not be, for extinction is the common fate of all species - and they cannot all take their ecosystems with them [17].

Rich countries cannot be blamed for all the miseries of the LDCs. The challenge of the industrial revolution was not taken up by the LDCs. South Asia was prevented by the British to industrialize. But Thailand, China and Latin America were free, still they did not industrialize. The economics Nobel Laurate, Sir Arthur Lewis of Jamaica gives the example of Australia and Argentina [18]. These two countries began to grow rapidly at the same time, the 1850s, and sold the same commodities - cereals, wool and meat. In 1913 their incomes per capita were among the world's top ten. The Argentines blame their failure to industrialize on British interests but the British had even more influence in Australia. Argentine politics was dominated by the landed aristrocracy whereas Australia was dominated by the urban communities.

The low price of primary products is to the advantage of the industrialized countries - be it agricultural raw material or minerals. Rich people in the LDCs prosper by exporting primary products - they are a part of the international vested interest against the industrialization of the LDCs. The LDCs have to come out of the grips of the merchant class and encourage entrepreneurship. Pollution of the environment due to industrial activity is a nonproblem in most of the LDCs. On the contrary, many people die because there is no chemical, pharmaceutical or fertilizer industry If the MDCs really mean to help the LDCs, they have to let the LDCs "pollute" themselves. MDCs have to lower the trade barriers, which in any case would also increase their own welfare.

We have to go forward. Problems are different for different generations. I do not want to go back to the Athens of Pericles and Solon, however golden it was. For there was slavery in the golden Greece. Present desire to fall back on fuel wood technology propagated specially by the pessimists who hark back to the quasi-Arcadian life of the country side, can at best be naive. Indiscriminate use of biomass energy encompassing woodfuel, biogas and alcohol might lead to environmental disaster and more suffering. If not carefully implemented it could increase the rate at which forests are depleted, speeding up desertification, influencing underground water level and competing with food crops.

The old fire that Prometheus stole from the Olympian gods cannot be burnt forever, it must be replaced by something new.

Most of the technology already exist, we have to utilize them. The Swedish participants in the NGO Forum of the UN Conference on New and Renewable Sources of Energy praised the virtue of renewable energy. I do not doubt their sincerity. Sweden is a large, sparesiy populated country with huge forests and plenty of hydroelectricity. Still they voted with a 60% majority for the nuclear energy. LDCs find it hard to have faith in the New Energy Gospel.

In the "1984" series published in the New Scientist in 1964 the Physics Nobel Laureate Professor Abdus Salam of Pakistan said:

> I would like to live to regret my words but twenty years from now, I am positive, the less-developed world will be as hungry, as relatively underdeveloped, and as desperately poor, as today. And this despite the fact that we know the world has enough resources - technical, scientific and material - to eliminate poverty, disease, and early death, for the whole human race.

It would be enough if at least the attitude in the North were as desired by the enlightened self-interest of the Brandt Report [19]. Joan Robinson [20] correctly diagnosed the attitude in the North:

> The prosperity of others is not desirable for their sake, but as a contribution to our comfort; when their prosperity seems likely to threaten ours, it is not desirable at all.

LDCs have different problems, probably different environment. Why should the LDCs care about the doubling of the carbon dioxide concentration in the atmosphere? LDCs will probably profit from a global warming. Wigley, Jones and Kelly [21] reports that:

> The most important features of a warm, high-CO_2 world are decreases in precipitation over most of the US, most of Europe and Russia and over Japan and increase in precipitation over India and the middle east. For India the increases vary from a few percent in Bangladesh and along the eastern coast to almost 100% in the north-west.

700 ppm of CO_2 in the atmosphere could be worse than 350 ppm. But an atmosphere charged with the fear of dying a nuclear death is polluted. An environment is already polluted in which for a large number of the population death is the only liberty from an utterly miserable life. It is not enough to prognosticate doom. The "inevitable large-scale global famine" predicted to occur during 1975-80, has not materialized. Human organizations are more robust than the neomalthusians consider them to be. The meaningful application of science and technology and rapid economic growth is our only hope. Technology can stretch the frontier of the human environment to where it should be - at the edge of the Universe.

8. What can be done?

Modern societies need a lot of infrastructure. The power structure in any society with a considerable infrastructure is similar to that of an ancient empire. In the modern high technology society, the divine king with his priests and courtiers has been replaced by the Technostructure (a term coined by J.K. Galbraith to denote the top people in science, technology, military, industry, party and administration). Organized labour and technology based small firms have replaced the merchants and craftsmen. Unorganized labour and the non-technical small economic units are the least privileged.

Fig. 5 here

The differences within a society have their counterparts on a global scale. Poor countries have less information. The problem of freeing people from poverty is not how to feed them. Poor countries need technology to produce their own food. It is true that different societies have different capabilities to gain from technological development but certain economic activities generate more (technical and non-technical) inventiveness than others in a given society. The way to development is to identify and pursue economic activities which make people more inventive.

It is doubtful whether only technical innovation can bring about large scale economic recovery. We have to, among many other things, innovate in the finance sector, have to innovate mechanisms which would reduce international and intranational disparities. Unequal distribution is a major source of armed conflicts among the nations and within a nation.

We need organizational and intellectual innovation which will enable us to avoid major economic crisis. Enhanced research activity is needed in many sectors. Let us take the example of climatology. We still do not know how the global climatic system will react to increased industrial and agricultural activity [22]. The Mycenaean civilization was destroyed by erratic climate [23]. Homer in the Iliad described the Mycenean decline as an act of the Olympian gods. Although the present destructive capacity of the superpowers (and smaller powers) will make the Olympian (and the Himalayan) gods blush, a vast amount of money and intellect is being spent to increase this destructive capacity. If resources were diverted from the military sector, we could at least hope for a better and safer future.

Resource management became a necessity for human societies when humanity invented agriculture. Recorded history tells us that a considerable part of the world population has always lacked the basic material necessities required for a decent life. Conflicts and suffering have arisen both from the unequal distribution of natural resources and from the inability of some societies to utilize those resources they do have. In the management of natural resources therefore one should strive to redress the balance.

Innovation is the key to better management of available resources. But most of R & D activity is not oriented to the needs of the poor countries or to the needs of the consumers in the rich countries. An industrial policy that could control industrial evolution through the selection of useful innovation would be a major achievment.

An increase in the degree to which individuals, groups and nations are linked to the information system as a whole will be a great advance as it will reduce the power of the manipulators. The capacity of people to interpret information which concerns them must increase, so that they can choose new innovation or discard old modes of production irrespective of whether the capital or the organized labour lose in the short run. The problems that concern us all cannot be solved by a small group.

The fifth Kondratiev is around the corner. This time the poor countries will have to be given a share of the growth. Marshall plan made it possible for many countries to grow faster than they otherwise would.

Developed countries must cooperate. If they do not lower the trade barrier, the manufactured goods from the poor countries cannot be sold. The fear of the trade unions and the politicians that the income in the rich countries will go down if their market is opened for poor manufacturers is ill-founded. After the second world war the USA produced half of the Gross World Product. Now it produces less than a quarter. But the Americans are now richer and with them the Japanese and the Europeans have also become rich.

Global cooperation is necessary and the economies must grow. The environmentalists' plea for zero growth is utopian. How could their demand for more public goods be met if the economies do not grow? Growth in production in the developed countries is necessary because many goods are badly needed in the poor countries.

If there should be a peaceful growth of the world economy as a whole, the poor countries will have to be integrated more to the world economy. Their role cannot further be restricted as exporters of primary products and importers of weapons. Novel financial instruments will have to be developed to make the growth equitable.

The best policies to follow are, in my opinion:

1) To lower the trade barrier, so that purchasing power can be generated in the LDCs. This will speed up the diffusion of modern technology.

2) Biotechnology is going to be a major component of the next phase of development. Most of the biotechnology research is done to produce expensive pharmaceuticals. More resources must be allocated to the food and agricultural sector. Better agriculture will help the poor countries to save a considerable amount of foreign exchange needed to import technology.

I have not filled up the row in the fifth Kondratiev in Table 3, anticipating that the present cycle is the last one. I hope that we will innovate mechanisms to avoid major disequilibria, which, of course, presupposes an equitable distribution of wealth and opportunities. Inequality makes the system not only inequitable but also inefficient. It is as true of intranational as of international distribution of income, wealth, and opportunity.

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	Energy use per capita (kilograms of coal equivalent)	GNP per capita (US Dollars)	Life expectancy at birth (years)	Enrollment in secondary schools as percentage of age group	Population per Physician
Ranking					
1	> 5,000	> 10,000	> 70	> 80	< 1,000
2	> 1,000	> 1,000	> 60	> 60	< 5,000
3	> 500	> 500	> 50	> 40	<10,000
4	< 500	< 500	< 50	< 40	>10,000
USA	1	1	1	1	1
Sweden	1	1	1	1	1
Kuwait	1	1	1	1	1
Cuba	2	n.a.	1	2	2
Mexico	2	2	2	3	2
China	3	4	2	2	2
Malayasia	3	2	2	3	3
Zambia	3	3	3	4	4
Morocco	4	3	3	4	4
Bangladesh	4	4	4	4	4

Table 1. The correlation of Energy and other indicators in selected countries (1984).

i	A_i	g_i	b_i	$P_i(T>T_o)$	$P_i(T<T_o)$
1	Proton	2	0	$1-\gamma(T)$	$1-2\gamma(T_o)$
2	Neutron	2	-1·30	$\gamma(T)$	0
3	Helium-4	1	6·73	0	$2\gamma(T_o)$
4	Iron-56	1	8·41	0	0

Table 2. The four nuclear states

Name of the cycle	Prosperity	Recession	Depression	Recovery
Textile	1781-1800	1801-1813	1814-1827	1828-1842
Railway	1843-1857	1858-1869	1870-1885	1886-1897
Electricity/Chemical	1898-1911	1912-1925	1926-1939	1940-1952
Control	1953-1966	1967-1979	1980-1989	1990-2000
Information				

Table 3. The Kondratiev cycles.

Figure Captions

Fig. 1. Evolution of Nuclear Exergy in the Universe.

Fig. 2. Schematic representation of an ancient empire. The net flow of exergy is shown with arrows.

Fig. 3. Parellel.lines connecting the vertices are isoexergy (continuous) lines and isoinformation (broken) lines. Spreng gives the value t=0, to the vertex "low frequency activity". This means that tasks are performed very quickly. On an isoexergy line, a task can be performed faster by using more information and similarly on an isoinformation line, more use of exergy increases the speed of performance. The triad shows that exergy, information and time are substitutes.

Fig. 4. Spread of telephone (PHONE), black and white television (TV) and colour television (COL TV) among the West German households. Upper, middle and lower income groups are indicated by 1, 2 and 3. Telephone was introduced in 1877, television in 1948 and colour television in 1968. Data is taken from ref. 11 .

Fig. 5. Schematic representation of a modern society. Power increases in the vertical direction, the net flow of exergy is shown with arrows. Professionals include technology based small firms. Unorganized labour include small scale nontechnical economic activity. Compare with fig. 2.

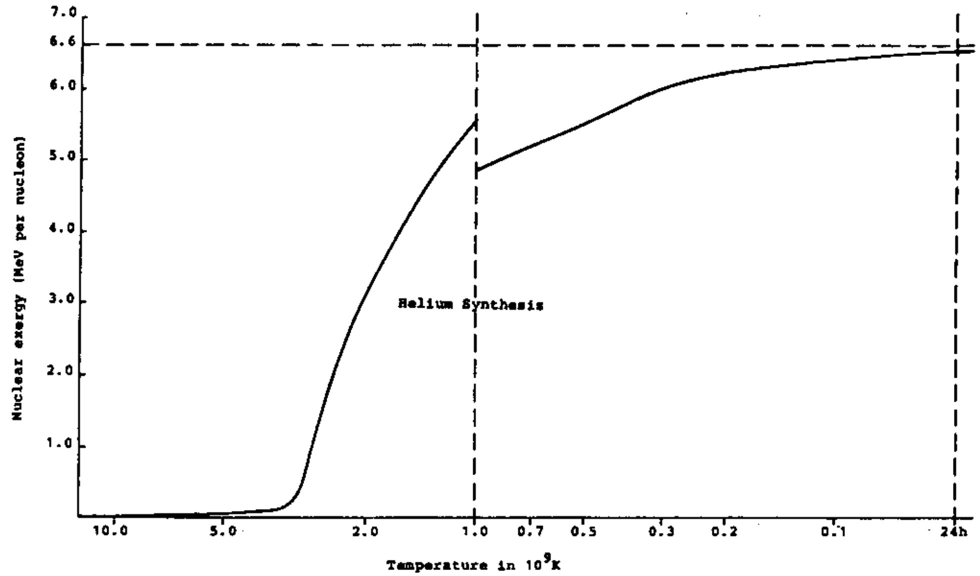

Fig 1

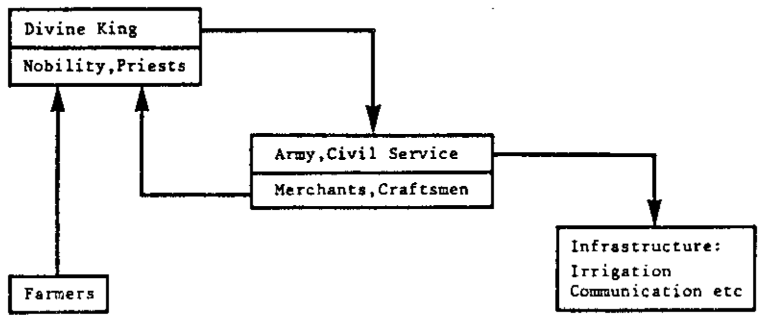

Fig 2

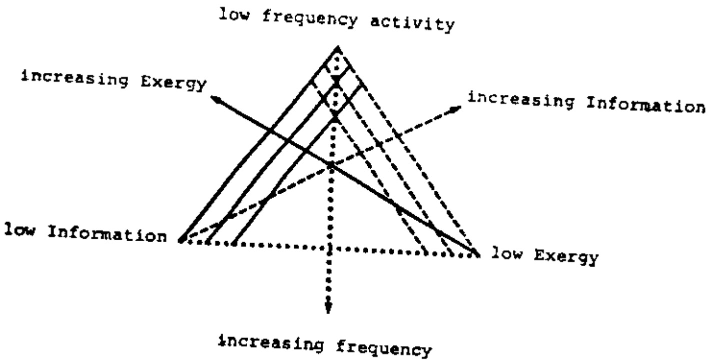

Fig 3

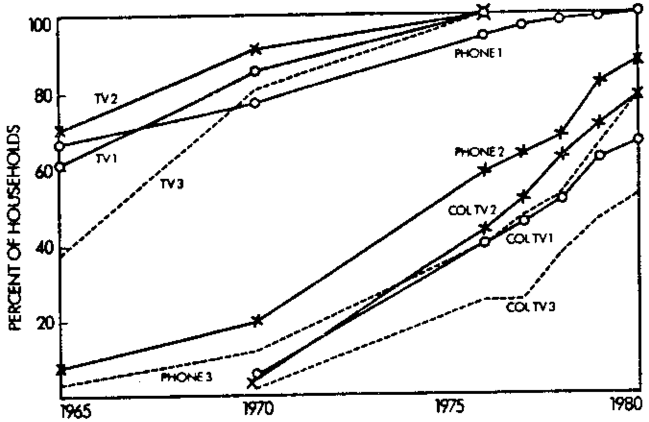

Fig 4

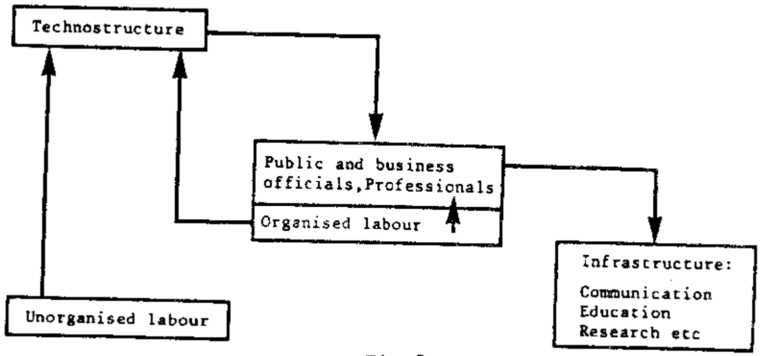

Fig 5

PHYSICS IN MICROELECTRONICS AND MICROELECTRONS IN PHYSICS

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Abstract :

Modern semiconductor technology and its many different facets such as micro-electronics, optoelectronics, integrated optics, solar energy conversion, etc... have their origin in solid state physics. However, because of their enormous economic impact, their development has been so rapid and has lead to such a high degree of complexity and sophistication, that to the newcomer in the field, the links between solid state electronics and solid state physics are no longer evident.

The processes involved in the production of integrated circuits and solid state lasers afford very instructive examples on which to demonstrate the impact of physics on semiconductor technology. Processes discussed include :

- Purification of silicon
- Crystal growth
- Liquid and vapour phase epitaxy
- Photo- and electronbeam lithography
- Mask production
- Wet and dry etching
- Doping and metal deposition, etc...

The inverse phenomenon, i.e. the impact of semiconductor technology on physics will be demonstrated on examples involving two-dimensional electron gases. Such gases can readily be obtained in "synthetic" layer structures, produced by molecular beam epitaxy and in the depletion layers of field-effect transistors

with MOS geometry. The examples discussed involve

- The multiple potential well laser and
- the "von Klitzing experiment"

1. Introduction

The activities of the Institute of Applied Physics which I direct are centered on semiconductor physics. We grow a large variety of monocristalline and thin-film semiconductors and try to characterize them by measuring their electrical and optical properties. We do not, however, have activities in the field of semiconductor technology, i.e. we do not produce micro- and optoelectronic semiconductor components.

In the light of the extremely rapid, worldwide development of micro- and opto-electronics and of their technology, it was only normal that we should start pondering about questions like:

- Can physics or, more particularly, semiconductor physics still contribute validly to semiconductor technology ?
- Does semiconductor technology still pose interesting problems to the physicist ?
- What can semiconductor technology contribute to physics ?

It is the aim of this talk to show that, on the one hand, physics has largely contributed and still is contributing to the discovery of new semiconductor applications and to the development of the corresponding technologies. Semiconductor technology, on the other hand, permits many beautiful physical experiments which would not be possible without it

2. Physics in Semiconductor Technology

Let me begin with the observation that the first semiconductor applications - Se rectifiers, PbS detectors and the Ge transistor - were developed by physicists. In the late forties, semiconductor technology and -physics were one and the

same thing : Each measurement on a semiconductor was at the same time physics and exploration of possible applications. This is no longer the case today : In order to get semiconductor components with optimum performances very complex technologies had to be created and to bring the costs of production of these components down, very efficient micromanufacturing processes were developed. As a result of this, the connection between semiconductor physics and the microstructures produced by micromanufacturing is only decernible with difficulty.

The lack of transparency of technological and manufacturing tendencies is amplified by the speed of their evolution. Let me remind you that the transistor was invented in 1948, that Fairchild produced the first integrated circuit consisting of 4 transistors and 4 resistors in 1961 (fig. 1), that today circuits containing up to 100'000 electronic gates are currently produced and that 1'000'000 gates have been realized on some experimental chips.

And there is yet another factor contributing to the complexity of modern semiconductor technology, i.e. mass production. To illustrate this, let me show you some pictures from the high purity single crystal production facility of Wacker Chemitronics in Germany (capacity ∿ 100 tons/year; figs 2 to 4). Purification of the technical grade Si is achieved through the Siemens process via the production of the volatile trichlorosilane

$$Si + 3HCl = SiHCl_3 + H_2 \quad ,$$

the subsequent destillation of $SiHCl_3$ and the deposition in a van Arkel-like process of Si on a hot Si rod. Single crystals are produced by pulling from the melt and/or zonefloating. The crystals are then shaped into circular rods of 2, 4 or 6 inches diameter on which flat faces are milled to indicate conduction type (n-, p-type) and crystal orientation. Next the rods are cut into thin (200-500 μm) slices which are polished and oxydized. It is in the form of these slices-the wafers - that the manufacturer of integrated circuits will normally obtain his Si crystals, his "raw material" (see e.g. (1)).

Physicists, physical chemists and chemical as well as electrical engineers have obviously largely contributed to develop the processes involved in the production of high purity Si single crystals and to bring them to today's perfection. However, the physics and chemistry of these processes are so well known that I need not go into any details here. What is perhaps less known is the fact that not only the purity and the perfection of the single crystals is controlled by physical methods (resistivity and carrier life-time measurements, X-ray diffraction, electron microscopy, etc...), but also the purity of the gases (H_2, HCl) and of the volatile $SiHCl_3$ used in the production of the basic high purity polycrystalline material. Thus H_2 of unknown purity is tested by using it as transport gas for $SiHCl_3$, whose quality has previously been established in the deposition of poly-Si. From the poly-Si thus obtained single crystals are pulled and their resistivity is measured. Only if the resistivity of these crystals comes up to specifications will the H_2 be used in the production line. The control of the quality of HCl and of $SiHCl_3$ is carried out in an analog manner.

Although the Siemens process, zone-floating and crystal pulling form the center of today's Si-technology, considerable efforts are made to develop new and cheaper technologies. Perhaps the most important among them is the plasma-deposition of amorphous Si : H films. The prospect of producing cheap, large-area solar cells is so enticing that an increasing number of physicists and chemists have in the past five years devoted their time and effort to a-Si : H (2). However, the big break-through has not come as yet : the only commercially available a-Si : H photocell today serve - rather trivially - as powersupplies for wrist watches. It is my firm conviction that if plasma-deposition of Si is to develop into an industrially important technology, then the physics and chemistry of the electric discharge in SiH_4 and in other volatile Si-compounds has to be studied in much more detail.

Going back to the Si-wafers let us next consider the physics of the micro-manufacturing processes which permit integrated circuits to be engraphed on them (fig. 5). These processes are generally known under the name of photo-lithography (3). In a first step a layout (fig. 6) of the circuit is produced, nowadays usually with the aid of a computer controlled pattern generator.

Important software libraries exist and are continuously expanding to facilitate and to render more efficient this computer-assisted design of integrated circuits. The transcription of the lay-out onto the Si-wafers involves a series of manufacturing steps such as etching of photoresist and underlying SiO_2 layer (fig. 7), diffusion or implantation of impurities (fig. 8), deposition of the metallic interconnections of the circuit elements, etc..., for each of which a mask (fig. 6) has to be made. Subsequently each mask is imaged on a thin photo-sensitive film (photoresist) deposited on the Si wafers before each manu-facturing step (fig. 7).

Since several hundred identical circuits are to be inscribed on one wafer side by side, mask production involves a photographic reduction as well as a "step and repeat" operation, both of which have to be accurate to within a fraction of a micron over the whole surface of the wafer. Obviously, considerable efforts in optics and mechanics have gone and are still going into theses processes. And this also holds for the imaging of the masks on the Si wafers. Here the alinement of successive mask images is very critical indeed, and with the advent of "very large scale integration" (VLSI) is often circumvented by selfalinement proceedures involving the deposition of multiple oxide and nitride layers on the wafers.

Critical also are the SiO_2 and Si_3N_4 etching processes. Wet etching techniques today have all but completely been replaced by plasma etching. But here new problems arise. Underetching (fig. 9) of the photoresist and redeposition of removed material result in an overall loss of resolution in the etched structures. Down to dimensions of about 0,5 microns, practical solutions to these problems exist (fig. 10), but they are largely based on trial-and-error receipts which are not publicly accessible : the physics and chemistry of plasma etching are still very badly understood today.

The resolution of photolithography is ultimately limited by the wavelength of the employed light. Efforts have therefore been made to use ultraviolet and X-ray sources. Moreover, mask production by electron-beam lithography (figs. 11 and 12) is becoming increasingly popular, not only because of its high inherent resolution, but also because e-beam writing can readily be controlled by

computers. Unfortunately, e-beam writers are too slow to permit direct exposure of the wafers, but the highly resolved e-beam masks can readily be used in connection with the X-ray source of the future : the synchrotron. First experiments along these lines have proved the feasibility of this method. Thus, it appears that the optical resolution available at present is sufficient to afford lithographic reproduction of circuits with features as small as a few thenths of a micron (fig. 13). On this scale the limiting factors are the photosensitive films and the etching processes. The search for new, inorganic photoresists with ultrafine grains and for etching proceedures with even higher resolving power, therefore, is very active at present.

To end this brief and incomplete overview of the important role physics plays in semiconductor technology and in micromanufacturing we mention a joint development of physics and applied mathematics : two-dimensional modelling of semiconductor interfaces such as junctions and contacts. Indeed, the strive for ever smaller circuit elements necessitates the electrical profiles (impurity and charge carrier densities, potential distribution, etc...) of such interfaces to be described not only across the plane of the interface, but also across its edge. Considerable computational efforts based on finite elements and related methods are actually under way in most of the research laboratories of integrated circuit manufacturers.

3. Physics in Devices

Physics is, of course, the principal source of inspiration for the development of semiconductor devices. As examples we consider here the semiconductor (diode) laser and some of its more recent offsprings. It was physicists who recognized that p-n junctions operated in the forward direction afford the carrier inversion to be established, which is necessary for coherent light emission (fig. 14). However, the first semiconductor lasers were rather inefficient, because the population inversion is adversely affected by the diffusion of carriers away from the junction. To avoid carrier loss by

diffusion the double heterojunction laser was invented (5). A layer of p-type GaAs is sandwiched between two layers of n-type and p-type $Al_{.3}$ $Ga_{.7}$ As respectively (see fig. 15). Because the energy gap of $Al_{.3}$ $Ga_{.7}$ As is higher than that of pure Ga As, the edges E_c and E_v of the conduction- and valence bands form square wells which confine the electrons and holes to the p-Ga As layer (fig. 15, bottom). Moreover, since the refractive index of pure Ga As is higher than that of the alloy $Al_{.3}$ $Ga_{.7}$ As, the Ga As layer represents an efficient light guide for the emitted radiation. The simultaneous confinement of electrons and holes as well as of the emitted light leads to a considerable increase of the efficiency of the double heterojunction laser as compared to the simple junction laser. In particular, it should be mentioned, that the reduced threshold currents attained in this way, permit DH lasers to be operated continously at roomtemperature. A view of a DH laser in "stripe geometry" is shown in fig. 16, in which typical dimensions are indicated. In the insert a micrograph of the sandwich n-$Al_{.3}$ $Ga_{.7}$ As / p-Ga As / p-$Al_{.3}$ $Ga_{.7}$ As is reproduced.

Depending on the size of the optical cavity of the DH laser and on the injection current, the emitted light contains many different modes. However, single mode emission can be achieved by introducing a Bragg reflector into the cavity (see e.g. (5), (6) and (7)). Cavities providing "distributed feedback" can readily be manufactured by embedding (8) a grating of suitable spacing at one of the interfaces Ga As / Al_x Ga_{1-x} As as shown schematically in fig. 17. The embedding is done by first inscribing by ion-milling a grating on the Ga As substrate (fig. 18) which subsequently is covered by an epitaxial overgrowth of Al_x Ga_{1-x} As (fig. 19). The gratings shown in figs. 18 and 19 are third order and have a period

$$\Lambda = \frac{3\,\lambda}{2\,n} = 3700\ \text{Å},$$

where λ = 8 800 Å is the wavelength of the laser light and n = 3,56 the refractive index of the cavity.

The production of complex heterojunction lasers is possible only on the basis of technologies which afford very thin layers of differently composed semiconductor alloys to be deposited in a controlled manner one on top of the other. In the order of their development, these technologies are : liquid phase epitaxy (9), chemical vapour deposition (10) and molecular beam epitaxy (11). A typical experimental set up used in the production of heterojunction lasers by liquid phase epitaxy is shown in fig. 20. A graphite slide holding a precursor seed and a growth seed (the substrate of the structure) can move freely through a graphite barrel which, in different compartments contains various alloys of desired composition. In order to keep the alloy solutions in the different compartments in liquid form the barrel is maintained at about 800°C. Moving the slide step by step through the barrel, the alloys are successively freed from the oxide film covering their lower surface by the passing precursor seed. Simultaneously the barrel temperature is gradually lowered, so that each time the growth seed reaches a new compartment, a thin film of the corresponding alloy is deposited. Excellent light emission efficiencies have been obtained with laser diodes manufactured by this method. However, the method is too clumsy for mass production and therefore is mostly used for research purposes nowadays. To a lesser extent the same remark holds for chemical vapour deposition, and we therefore here only give a schematic view of a typical deposition reactor (fig. 21).

The most advanced technology for epitaxial crystal growth and the one that affords the best control of the deposited layers, is without any doubt molecular beam epitaxy. From the pioneering work of Cho (11) it has, over the past decade, developed into a most efficient manufacturing method for semiconductor devices with heterostructures (see e.g. (13)). A suitable substrate onto which layers are to be deposited is maintained at an elevated temperature in an ultrahigh vacuum vessel (figs. 22 and 23) A series of individually heated evaporation cells allow the substrate to be bombarded with different atomic and / or molecular beams which are collimated by a liquid-nitrogen cooled shroud. The shroud also serves to pump condensible gases. Shutters on each cell permit the beams to be initiated and interrupted in times which correspond to less than 1 Å growth of the deposited layers.

If molecular beam epitaxy is eminently suited for the production of complex lasers and other optoelectronic devices, its biggest success from the point of view of the physicist is certainly the fabrication of synthetic layer - or superlattice structures consisting e.g. of stacks of alternating Ga As - and $Al_x\ Ga_{1-x}$ As - layers (see e.g. (14) and (15)). In fig. 24 a scanning electron micrograph of such a superlattice is reproduced. As the individual layers can be made as thin as ∿100Å and since the forbidden gap of the semiconducting alloys vary abruptly from layer to layer, multi quantum-well structures can thus be produced, which afford the study of two-dimensional charge carrier gases. This subject will be treated in the next section.

4. Devices in Physics

The conduction and valence band edges of synthetic superlattice structures have the shape of periodic square well potentials (fig. 25, top). The electrons or holes occupying the low-lying states $n = 1,2,\ldots$ in these wells are confined within them and thus form two-dimensional Fermi gases. The corresponding density of states is shown in fig. 26.

During the growth by molecular beam epitaxy of a superlattice consisting of alternating layers of Ga As and $Al_x\ Ga_{1-x}$ As donors can be incorporated by simultaneous evaporation of Si. For appropriate values of x, the donor levels in the $Al_x\ Ga_{1-x}$ As layers lie above the bottom of the GaAs conduction-band and therefore are all ionized. The corresponding electrons together with those excited thermally occupy the lowest states in the conduction band of the GaAs layers and they form two-dimensional gases (fig. 25, middle). By suitably shuttering the Si evaporation source one can grow so-called "modulation doped" superlattices in which only the $Al_x\ Ga_{1-x}$ As layers contain donors while the Ga As layers remain donor-free (fig. 25, bottom; ref. (16)). The resulting situation is rather extraordinary : In an intrinsic region of Ga As one finds an electron concentration which corresponds to more or less heavily n-doped material. The absence of donors in the Ga As layers does,

of course, drastically reduce the ionized impurity scattering at low temperatures (T< 300K) where it would otherwise predominate, and unusually high electron mobilities are measured ($\mu > 10^4$ cm^2 $V^{-1}s^{-1}$ at liquid He (16)). In their recent article Drummond et al. (17) reported electron mobilities as high as μ = 115 000 cm^2 $V^{-1}s^{-1}$ at 10 K in a single period modulation doped $Al_{.25}Ga_{.75}As$ / GaAs heterostructure.

As was pointed out already by Dingle et al. (16) the high chargecarrier mobilities in modulation doped heterostructures open up new possibilities for the physicist. Low temperature transport studies on multilayer two-dimensional electron gases are particularly interesting in this respect. Here we only mention the strong anisotropy of the magnetoresistance : with the magnetic field perpendicular to the layers of the heterostructure Shubnikov - de Haas oscillations are observed at fields as low as 10 kG. When the field is turned into the plane of the layers the oscillations disappear completely, thus evidencing the two-dimensionality of the electron gas.

The "multi-quantum-well heterostructure laser" represents yet a second device permitting physical phenomena to be observed which are associated with the two-dimensional character of the electron gas in synthetic layer structures. The first such laser was described by Tsang et al. (18) and consists of a cavity formed by 14 Ga As quantum wells each ∿ 136 Å thick and separated by 13 $Al_{.27}Ga_{.73}As$ barriers each ∿ 130 Å thick. The confinement layers on either side of the cavity are n-$Al_{.27}Ga_{.73}As$ and p-$Al_{.2}Ga_{.73}As$ respectively. The corresponding energy band diagram is shown in fig. 27 (top). Within each Ga As conduction band well the two lowest electron states n = 1 n = 2 are marked. Also shown are the states n = 1 of the heavy holes (hh) and the light holes (lh) in the valence band wells. The wavefunctions (half a wave length of a sine) drawn on some of the energy levels are meant to indicate their occupation by electrons or holes respectively.

At threshold current lasing occurs first at about 8708 Å (fig. 27, bottom), i.e. at the high energy side of the spontaneous peak. This behaviour differs

markedly from that of normal DH lasers in which no such high energy emission has been observed. When the current is increased by about 10% new, much stronger lasing lines occur at 8745-8750 Å (fig. 27, bottom). Tsang et al. (18) interpret the emission at threshold as resulting from the n = 1 electron-to-light-hole recombination while the lower energy lines appearing at higher currents are believed to stem from the n = 1 electron-to-heavy-hole recombination. This assignement is consistent with the light-to-heavy hole splitting observed in excitonic spectra. Lasing lines associated with the confined levels n > 2 have not been found.

The successive occurrence of first the emission corresponding to the 1e-1h recombination and then of that involving the 1e-hh recombination can be explained as follows : when electrons and holes are injected at threshold from the n-$Al_{.27}Ga_{.73}As$ and the p-$Al_{.27}Ga_{.73}As$ side respectively, the more mobile light holes will move accross the multilayer to quantum wells near the n-side. In this region the density of the injected electrons is much higher than near the p-side and a population inversion between the electrons and light holes is achieved. As the injection current increases, more electrons reach the wells close to the p-side where the heavy holes are abundant, and emission corresponding to the 1e-hh recombination is possible. This interpretation is confirmed by experiments involving optical pumping. Since in this case no carrier transport is involved and the electron-hole pairs are generated throughout the whole multilayer cavity only the stronger 1e-hh emission is observed.

Synthetic superlattice structures of the type just described are not the only semiconductor devices in which two-dimensional electron gases are met. From this point of view the metal-oxide-semiconductor field-effect transistor (MOSFET) represents a most important tool for the physicist interested in basic solid state physics (19). In fig. 13 a crossection of a MOSFET is shown, and in fig. 28 its functioning is summarized schematically. In a p-Si substrate (base) two n-type aeras-source and drain - are incorporated and in the region between them and isolated from the base by a thin SiO_2 film, a metal gate is deposited. At zero gate potential (V_g = 0) the energy band profile across gate, oxide film and base is as shown in fig. 28 (middle).

With a positive gate voltage the bands in the p-Si are bent as indicated in fig. 28 (bottom) and a thin inversion layer containing electrons is formed in the p-Si just below the oxide film. This conducting n-channel, which runs from source to drain, constitutes a two-dimensional electron gas confined within the wedge shaped potential well appearing at the surface of the base for $V_g > 0$.

Let x denote the direction of the channel, x-y its plane and z the axis perpendicular to it. In this case the shape of the probability density of the confined electrons along z is as shown schematically in fig. 29 (bottom) (see also (19)). The density of states in the channel once again corresponds to that of a two-dimensional Fermi gas (fig. 26), and since all the electrons occupy the ground state n = 1 only, of the potential well, its value simply is :

$$N(E) = \frac{2\pi\, m^*}{h^2},$$

where m^* is the effective electron mass. If now a magnetic field H_z is applied to the MOSFET along the z direction the density of states splits up into a series of discrete Landau levels (fig. 30) located at energies

$$E_L = \frac{he}{2\pi m^* c} \,.\, H_z \,(i + \tfrac{1}{2}),\ i = 1, 2, 3...$$

and separated from one another by equal intervals

$$\Delta E_L = \frac{he}{2\pi m^* c} \,.\, H_z.$$

Each level contains all

$$N_L = N(E) \,.\, \Delta E_L = \frac{e}{hc} \,.\, H_z$$

states which in the absence of the magnetic field are comprised in the interval ΔE_L. The two-dimensional gas is thus fully quantized each electron orbiting with the cyclotron frequency

$$\omega_c = \frac{e}{m^* c} H_z$$

around the field lines.

What will happen to these orbiting electrons if, simultaneously with H_z, an electric field E_x is applied along the channel ? The two Landau levels i and $i + 1$ between which we suppose the Fermi level to lie are separated by ΔE_L. At low temperatures and at high enough magnetic fields this separation is much too big to allow for dissipative scattering of the electrons across the Fermi level. No current can therefore flow along the applied electric field. Rather, the orbiting electrons drift in the y direction perpendicular to both E_x and H_z. This means that the diagonal elements σ_{xx} and σ_{yy} of the conductivity matrix are zero. Moreover, the off-diagonal element σ_{xy} - the Hall conductivity - which normally depends on the scattering mechanism does, in the absence of any scattering at all, take the particularly simple form

$$\sigma_{xy} = \frac{Nec}{H_z},$$

where N is the two-dimensional electron density.

The electron density N in the conducting channel of a MOSFET is proportional to the applied gate voltage V_g (19). Making use of this fact, von Klitzing et al. (20; see also 21) carried out the following Hall effect experiment: in the geometry outlined in fig. 31 they measured the Hall resistance

$$\frac{V_y}{I_x} \sim \frac{1}{\sigma_{xy}}$$

of a MOSFET at H_z = 150 kG and at T ≈ 1.5 K. By gradually increasing the gate voltage they increased N, but since the density of states is a δ-function consisting of individual Landau levels, N can only increase in steps of

$$\Delta N = N_L = \frac{e}{hc} \,.\, H_z,$$

and does so each time the Fermi level E_F crosses a Landau level. If in particular E_F lies above the i^{th} Landau level, then

$$N = \frac{ieH_z}{hc}$$

and

$$\frac{V_y(i)}{I_x} \sim \frac{1}{\sigma_{xy}(i)} = \frac{H_z}{Nec} = \frac{h}{ie^2} \quad .$$

As V_g increases further $\frac{V_y}{I_x}$ will remain constant until E_F crosses the next Landau level, and on plotting the Hall resistance as a function of V_g one obtains the stepped curve shown schematically in fig. 32. At each plateau the ratio of the Hall voltage to the current is precisely $\frac{h}{ie^2}$ or, in other words, the von Klitzing experiment affords an absolute standard of resistance to be defined in terms of the finestructure constant

$$\alpha = \frac{e^2}{h} \cdot \frac{\mu_0 c}{2} \quad ,$$

where μ_0 is the permeability of vacuum. Conversely, accurate resistance measurements permit the finestructure constant to be determined with a new and independent method. Scientists of the National Bureau of Standards in Washington together with a group of physicists at the Bell Telephone Laboratories are actually developing the method so that by the end of 1981 measurements of α to within a few parts in 10^7 should be possible.

These are obviously most exciting findings which clearly demonstrate the importance of applying the results of semiconductor technology and particularly of microelectronics to basic solid state physics. But there is more physics behind the von Klitzing experiment than would appear from the very simple interpretation given here. Indeed, this interpretation is based on the assumption that the density of states of a two-dimensional electron gas in a magnetic field is described by a δ-function. But because of imperfections and disorder in the real MOSFET structures this is, of course, not the case : the Landau levels are broadened and while there exists a mobility gap between successive levels the density of states does not go

exactly to zero. This rises the question why the von Klitzing experiment works at all and why it does furnish a value for the finestructure constant, whose precision is comparable to that obtained with other methods. Such questions have given rise recently to a series of theoretical considerations (22, 23) which show, that if the interpretation given here is indeed oversimplified, it essentially gives the correct result. Small errors might arise from the thermal exitation of carriers to the mobility gap.

The quantization of the Hall resistance in a two-dimensional electron gas has not only been observed in MOSFETs. As mentioned earlier (17) two-dimensional electron gases are also formed at single period modulation doped $Al_x Ga_{1-x}As$/GaAs heterostructures. In this case the two-dimensional concentration N of electrons is constant and one cannot move the Fermi level across the Landau levels. However, the opposite is possible : by varying the magnetic field one can push successive Landau levels through E_F. Since the electron mobility in heterostructures is very high, quantization can be achieved (24) under less stringent conditions ($H_z \sim 80$ kG, T = 4 K) than in the Si MOSFETs.

5. Conclusions

In the introduction to this talk I have formulated three questions :

- Can physics still contribute validly to semiconductor technology ?
- Does semiconductor technology still pose interesting problems to the physicist ?
- What can semiconductor technology contribute to physics ?

The first two questions can now be answered in the affirmative. Thus, I have shown in section 2 that semiconductor technology draws heavily from physics and with the development of Very Large Scale Integration will continue

to do so at an ever increasing rate. In section 3, I have given a few examples of technological problems posed to and solved by phsicists

. how to render a junction laser more efficient ?

. how to produce a single mode junction laser ?

. how to produce multilayer heterostructures ?

The discussion in section 4, finally, of physical phenomena in two-dimensional electron gases clearly demonstrates how semiconductor technology, by rendering possible the study of such gases, has opened new fields to the experimental as well as to the theoretical physicist. The von Klitzing experiment is the most beautiful example in recent years of the strong interaction existing between semiconductor technology and basic physics. The scientist interested in solid state electronics is well advised to keep abreast of both.

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Captions

Fig. 1 : First integrated circuit consisting of 4 transistors and 4 resistors, produced 1961 by Fairchild.

Fig. 2 : Destillation columns in high-purity trichlorosilane production (after (1)).

Fig. 3 : A battery of modern float-zone machines for the production of monocrystalline Silicon (after (1)).

Fig. 4 : Silicon single crystal being pulled from the melt.

Fig. 5 : Engraphing the elements of an integrated circuit on chips and wafer.

Fig. 6 : From the layout to the final mask.

Fig. 7 : The photolithographic process :

a) exposure of photoresist through mask
b) selective etching of photoresist and SiO_2 layer
c) removal of residual photoresist

Fig. 8 : Diffusion of n-type impurities into a p-type substrate through the windows in the SiO_2 layer.

Fig. 9 : Underetching of photoresist : SEM-micrograph of squarewave grating etched into SiO_2 according to (4). The prismatic bars are the underedged photoresist.

Fig. 10 : SEM-micrograph of squarewave grating produced in SiO_2 with the highly directional, reactive sputter etching technique (after (4)).

Fig. 11 : Schematic representation of computor controlled e-beam lithography.

Fig. 12 : Electron beam pattern generator Cambridge Instruments EBMF-2 for use in e-beam lithography.

Fig. 13 : Minimum dimensions of actual metal-oxide-semiconductor field-effect transistors (MOSFET) :

Distance source-drain : $L \sim 0,5 - 1\mu$

Effective channel length : $L_{eff} \sim 0,25 - 0,5\mu$

Depletion layer thickness : $W_S \sim W_D \sim 0,25\mu$

Thickness of oxide below gate : $\sim 400 - 800$ Å

Fig. 14 : The principle of the junction laser. Under forward bias the electron-hole populations are inverted in the region of the junction and recombination gives rise to coherent light emission.

E_v : valence band edge

E_C : conduction band edge

E_F : Fermilevel; E_{F_n}, E_{F_p} : quasi Fermilevels

Fig. 15 : Double heterojunction laser : the confinement of electrons and holes in the junction region.

Fig. 16 : Double heterojunction laser in "stripe geometry".

Fig. 17 : Schematic view of a double heterostructure distributed feedback laser. w represents the width of the lasing cavity (after (8)).

Fig. 18 : Scanning electron photomicrograph of the surface of an ion-milled grating on a Ga As substrate (after (8)).

Fig. 19 : Scanning electron photomicrograph of a cleaved and etched section of a $Al_{.3}Ga_{.7}$ As layer grown epitaxially on a Ga As substrate with ion-milled grating (after (8)).

Fig. 20 : Reactor for liquid phase epitaxy of Ga As and related alloys (after (9)).

Fig. 21 : Schematic view of a chemical vapour deposition reactor for III-V compounds (after (10)).

Fig. 22 : Schematic view of a typical ultrahigh vacuum system for molecular beam epitaxy (after (12)).

Fig. 23 : The MBE equipment of the Institute for Microelectronics in the Federal Institute of Technology in Lausanne.

Fig. 24 : Transmission electron micrograph of $(GaAs)_n(AlAs)_m$ superlattices consisting of n (m) monolayers of GaAs (AlAs). Left : n = 8.0, m = 1.3; right : n = 6.1, m = 3.4.

Fig. 25 : Energy band diagrams for undoped (top), uniformly n-doped (middle) and modulation n-doped Ga As / Al_x Ga_{-x} As superlattices (after (16)).

Fig. 26 : Density of states ocrresponding to a two-dimensional carrier gas contained within a deep-well potential. The Fermi level lies between the states n = 3 and n = 4 of the deep well.

Fig. 27 : The multi-quantum-well heterostructure laser. Top : energy band diagram showing the n = 1 and n = 2 electron states in the conduction band and the n = 1 light- and heavy hole states in the valence band of the Ga As layers. Bottom : Emission of the MQW heterostructure laser (schematical, after (18)).

Fig. 28 : The MOSFET. Top : crossection. Middle : Energy band diagramm for $V_g = 0$ and bottom : for $V_g > 0$.

Fig. 29 : Schematic representation of the probability density ψ^2 of electrons confined to a square well (top) and a wedge shaped well (bottom) such as it occurs in the inversion layer of a MOSFET

Fig. 30 : The Landau levels in a two-dimensional electron gas (m^* = effective electron mass).

Fig. 31 : Hall geometry.

Fig. 32 : The Hall resistance $\frac{V_y}{I_x}$ as a function of the gate voltage V_g.

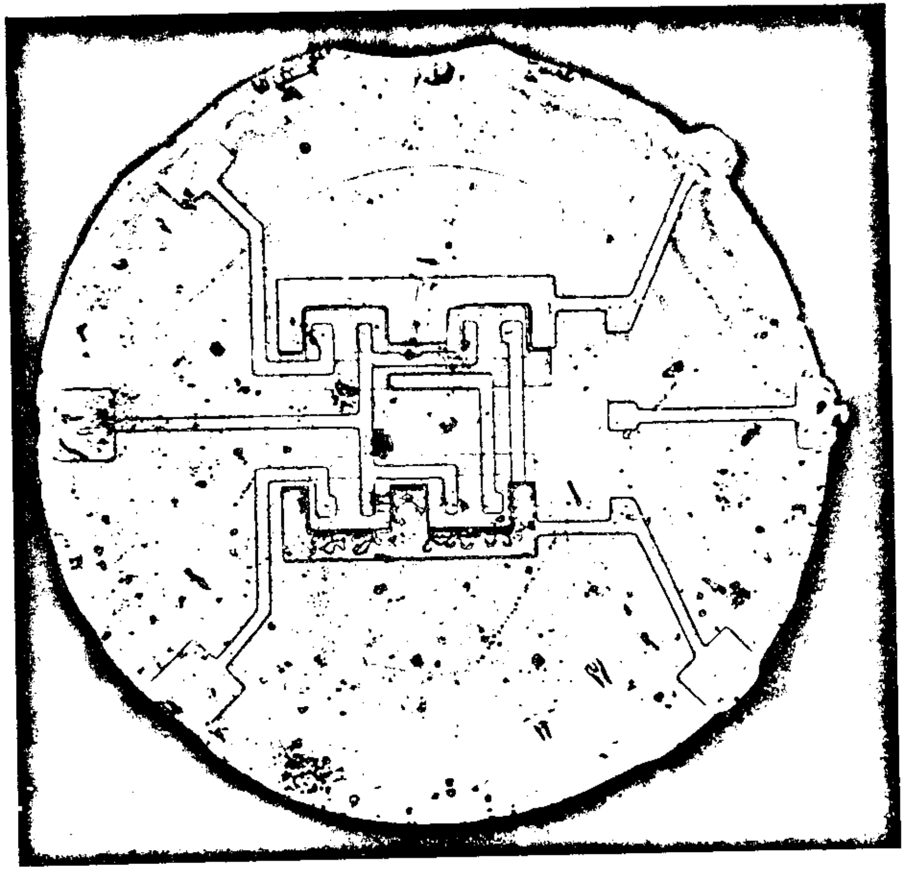


Fig.1

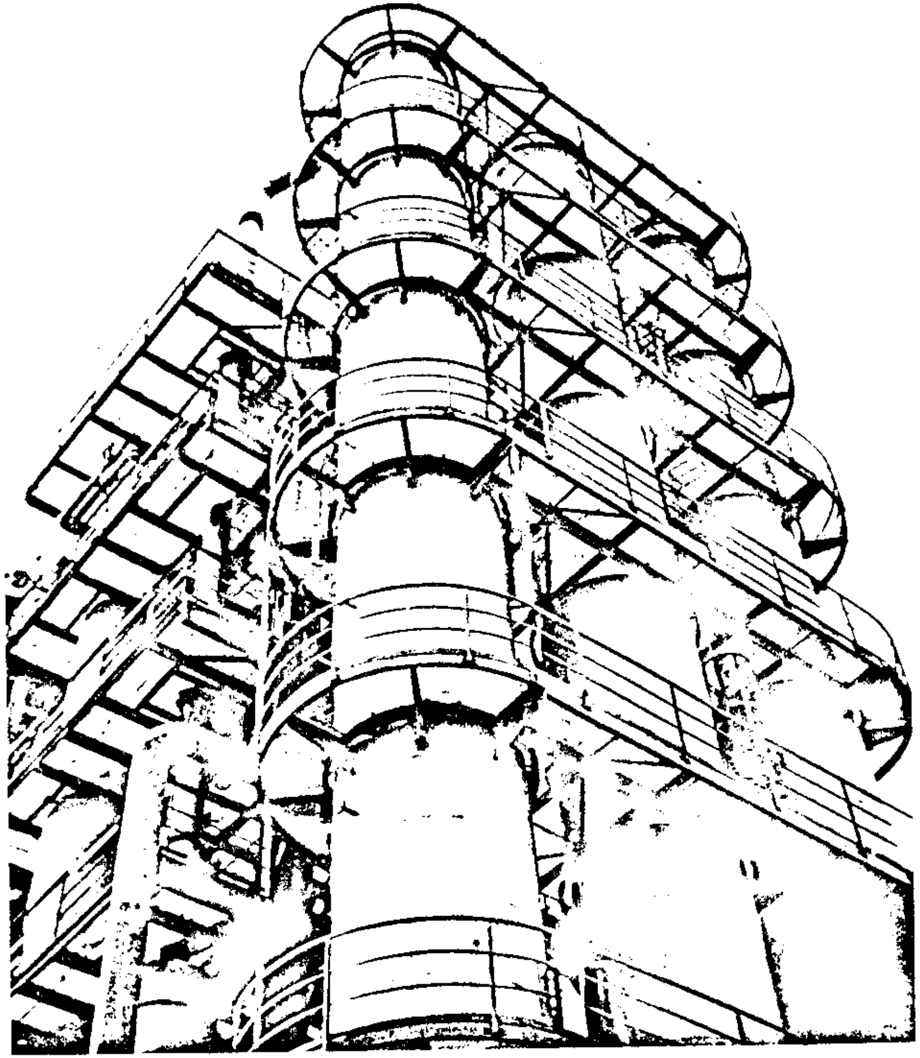


Fig.2

Fig.3

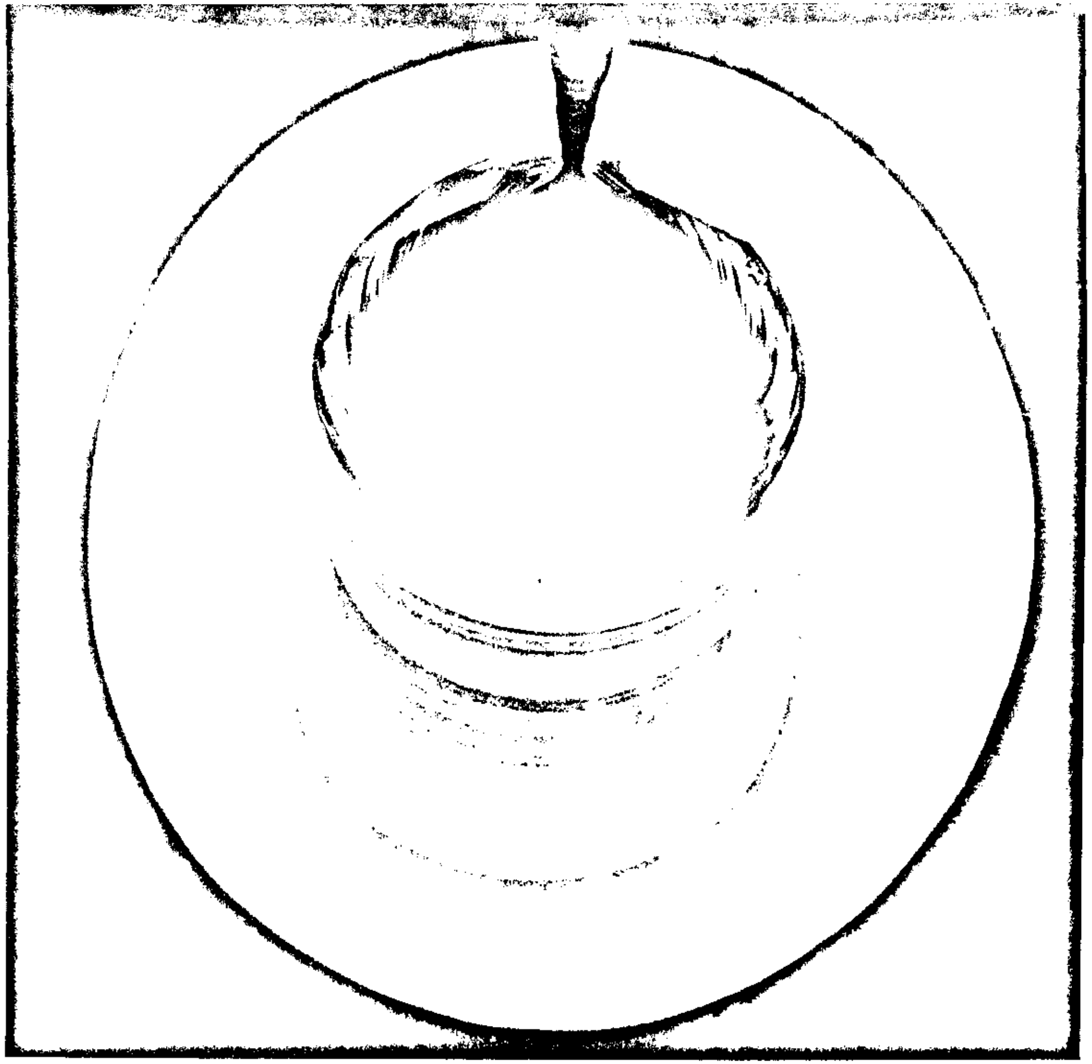


Fig.4

INTEGRATED CIRCUIT

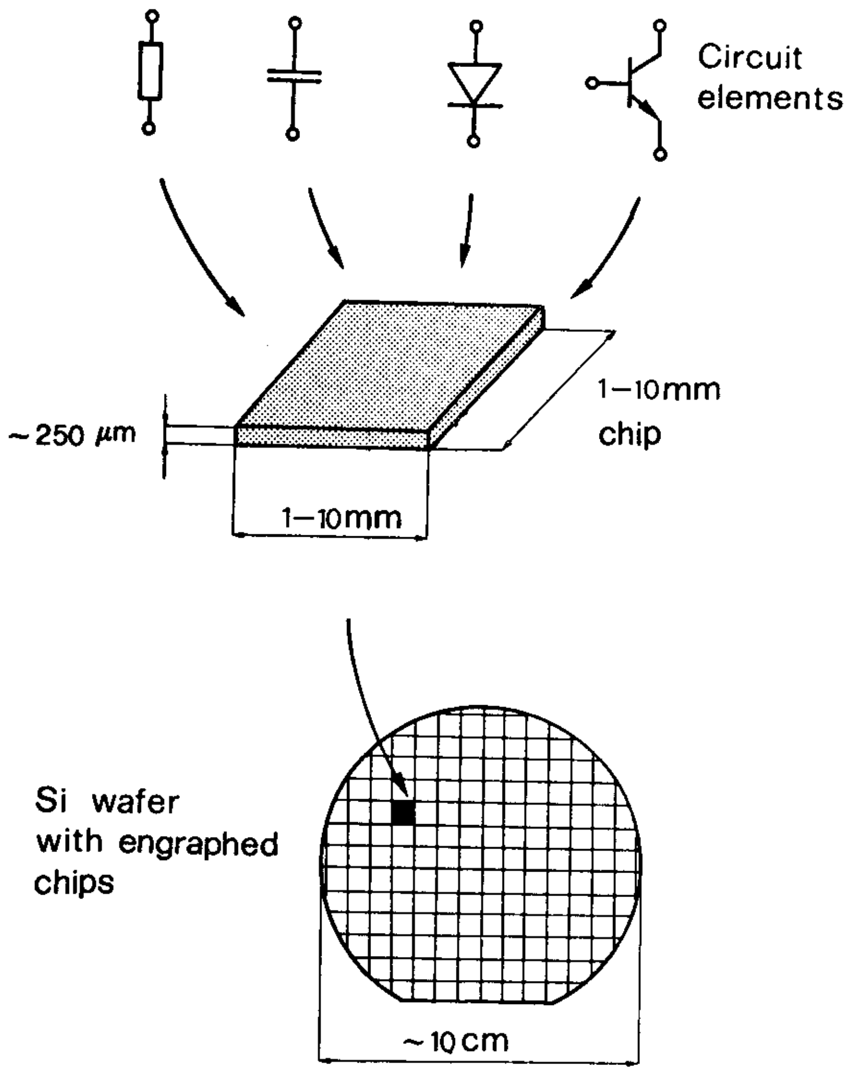


Fig.5

MASK PRODUCTION

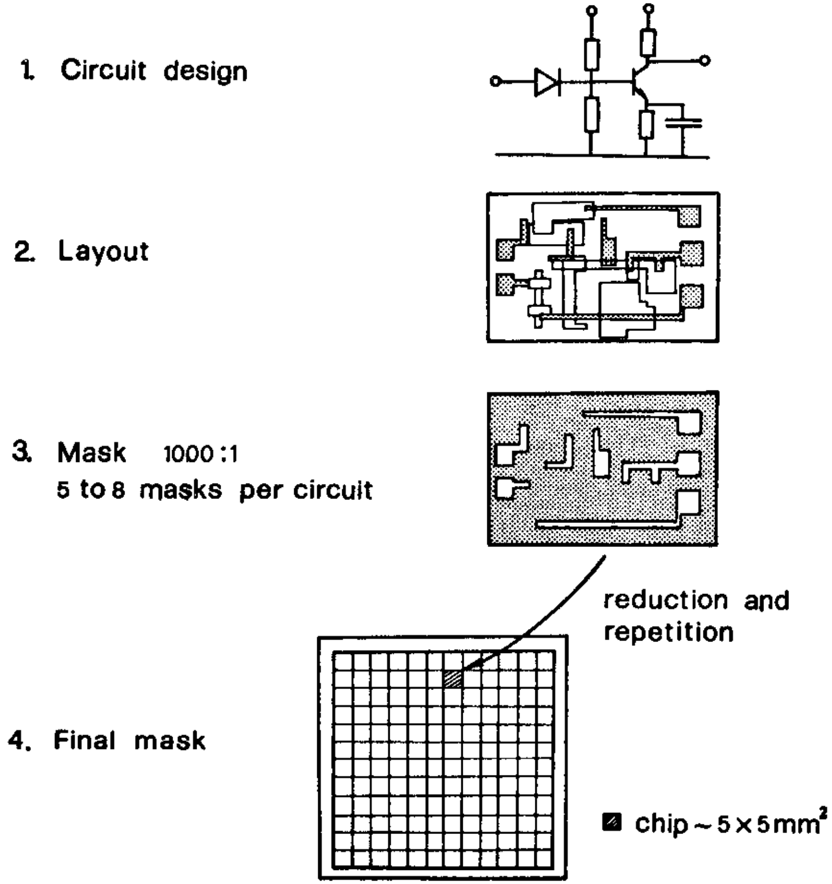
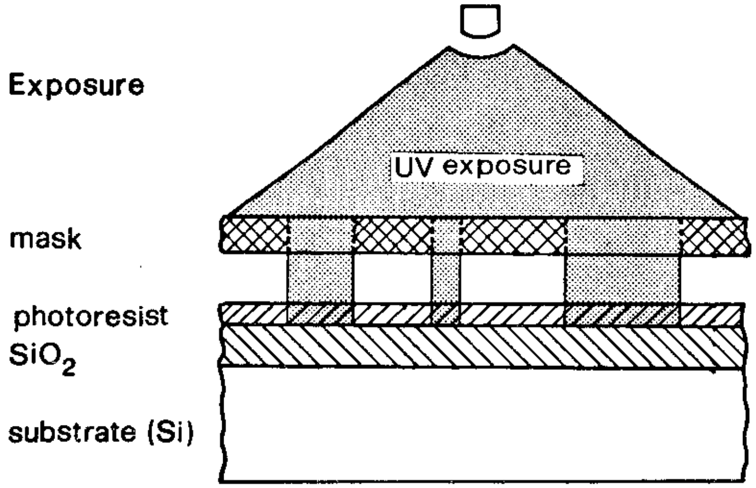


Fig.6

PHOTOLITHOGRAPHY

1. Exposure



2. Selective etching of photoresist and underlying SiO_2
3. Removal of remaining photoresist

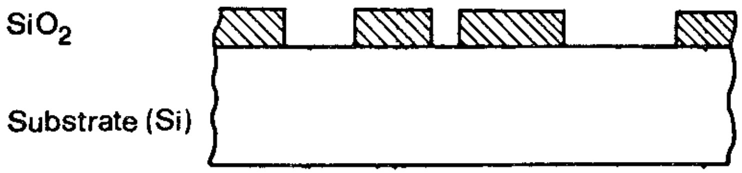


Fig.7

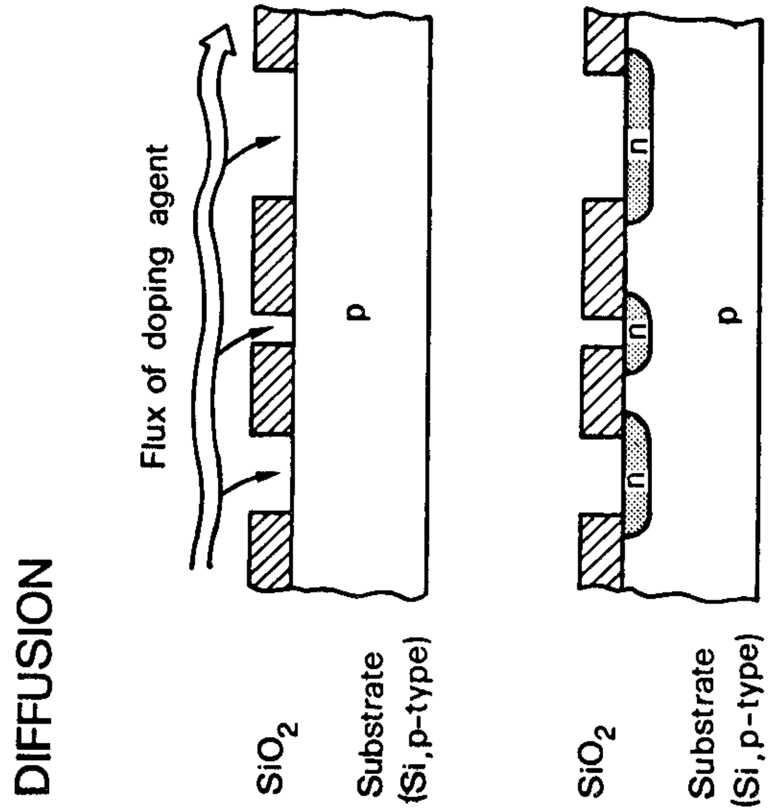


Fig.8

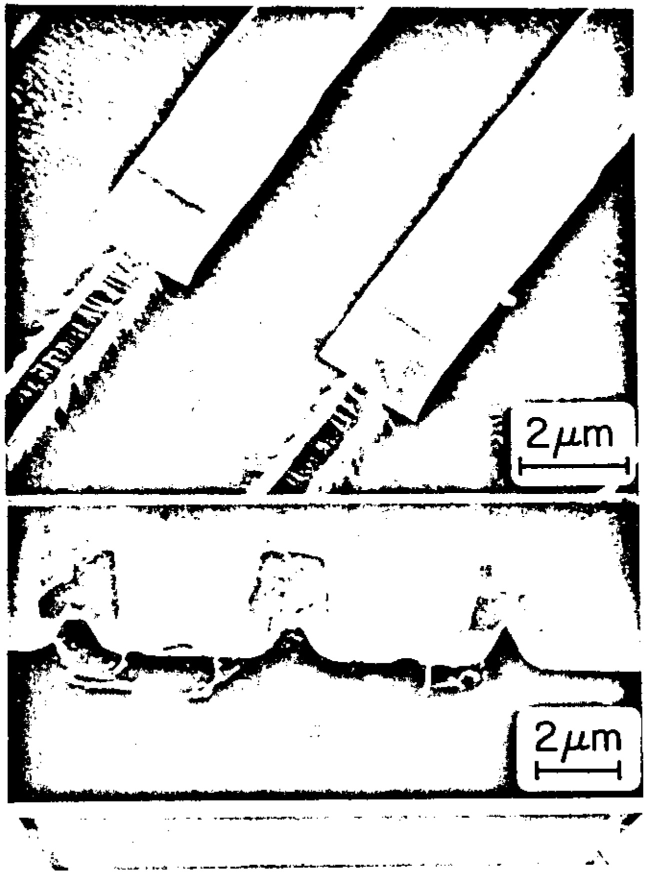


Fig.9

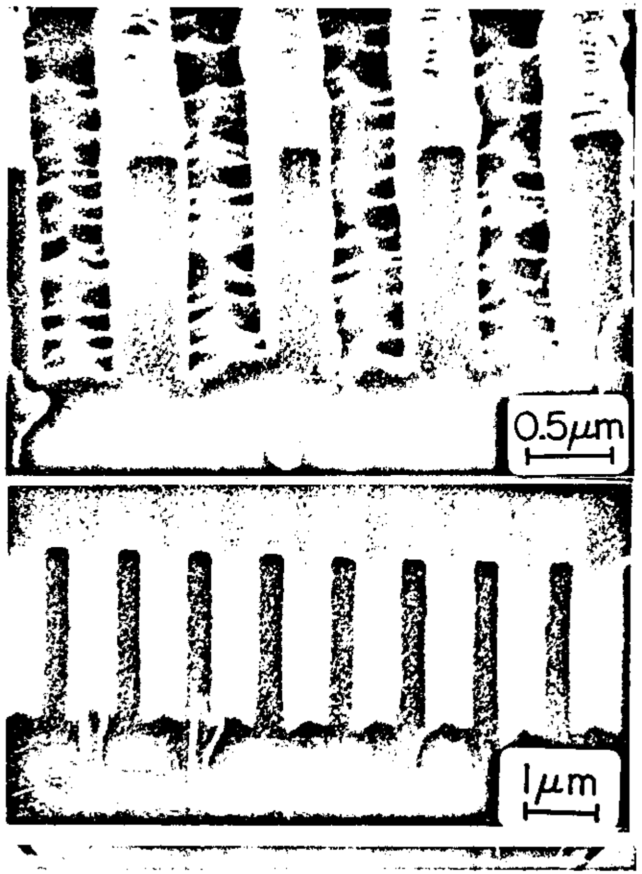


Fig.10

ELECTRON BEAM LITHOGRAPHY

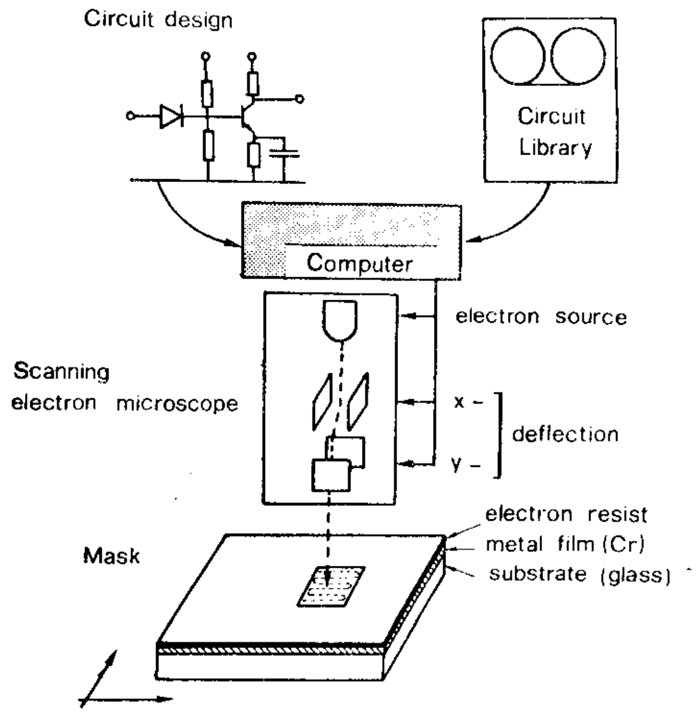


Fig.11

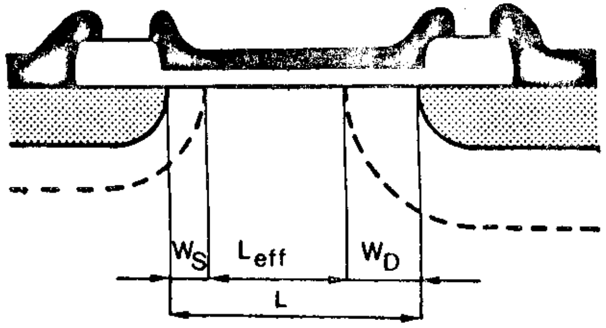


Fig.13

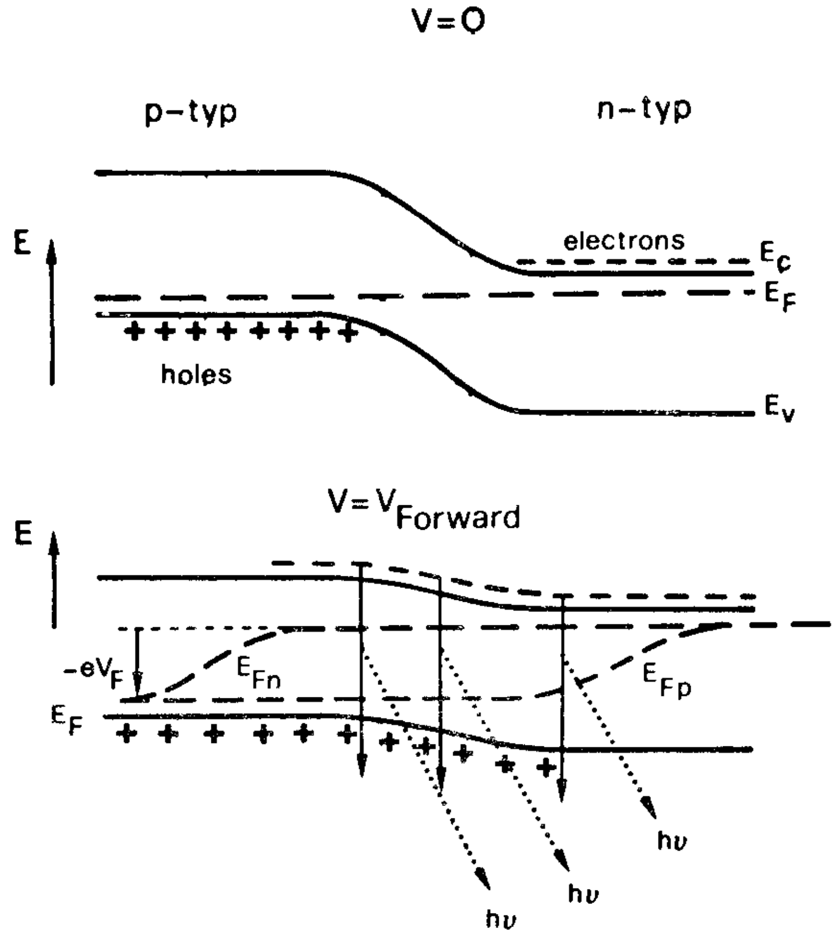


Fig.14

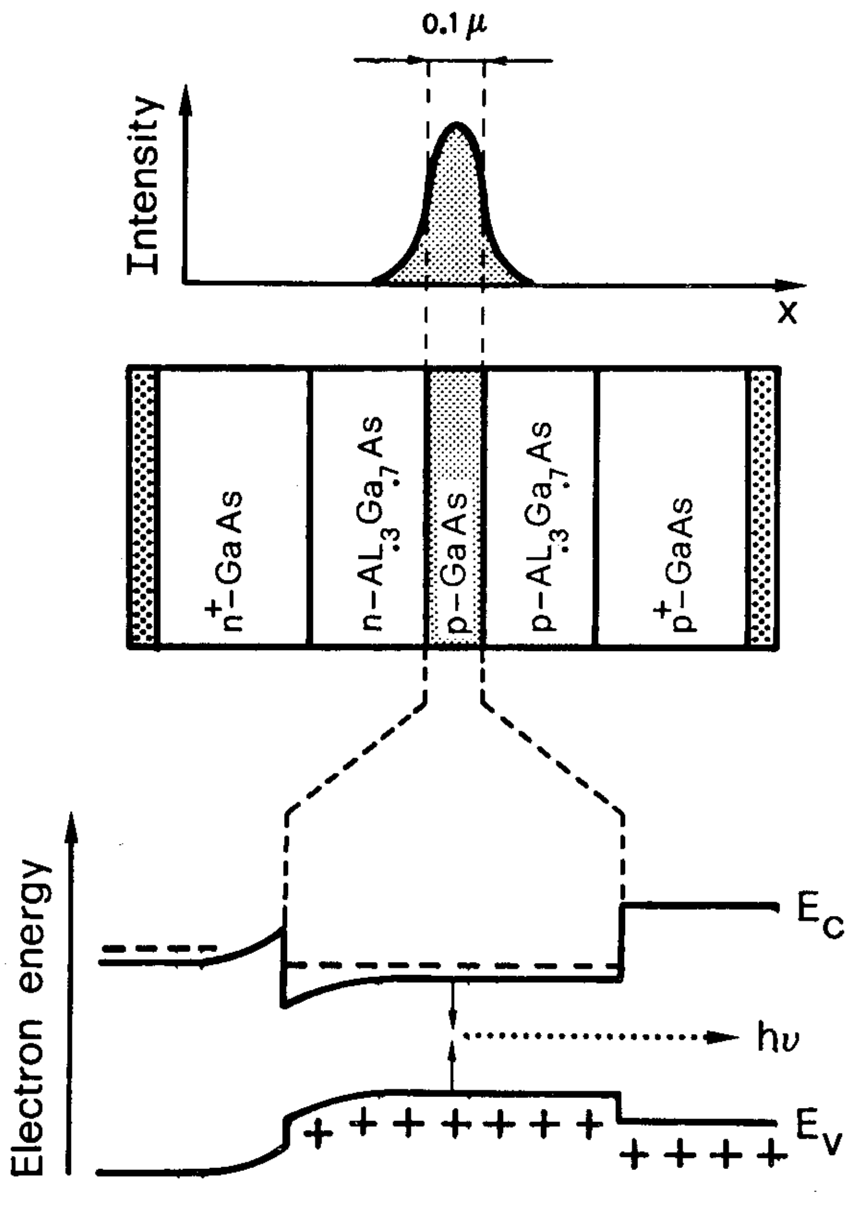

Electron energy
Intensity
0.1 μ
x
n^+–GaAs
n–$AL_{.3}Ga_{.7}As$
p–GaAs
p–$AL_{.3}Ga_{.7}As$
p^+–GaAs
E_c
hν
E_v

Fig.15

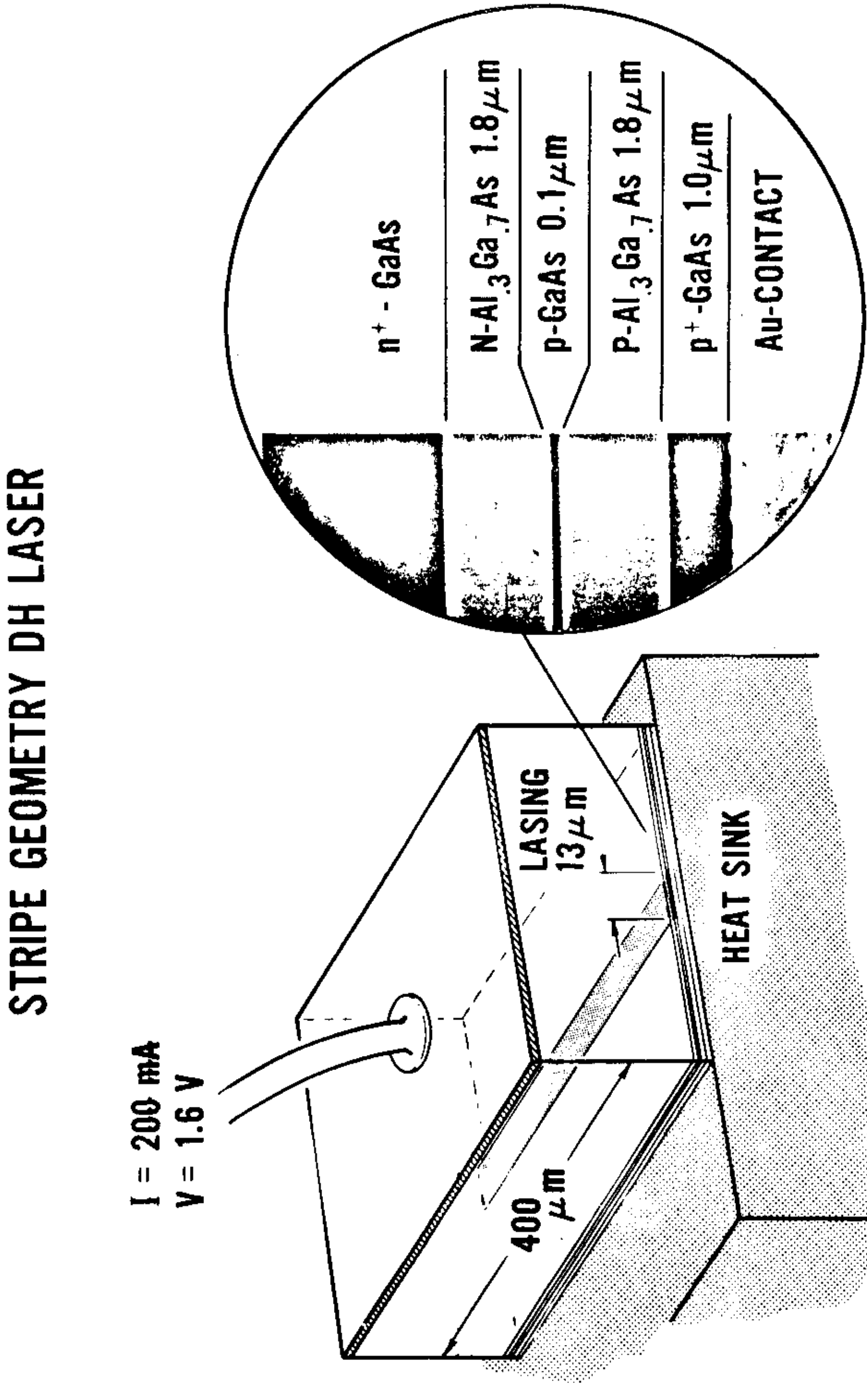

STRIPE GEOMETRY DH LASER
I = 200 mA
V = 1.6 V
400 μm
LASING
13 μm
HEAT SINK
n^+ - GaAs
N-$Al_{.3}Ga_{.7}As$ 1.8 μm
p-GaAs 0.1 μm
P-$Al_{.3}Ga_{.7}As$ 1.8 μm
p^+-GaAs 1.0 μm
Au-CONTACT

Fig.16

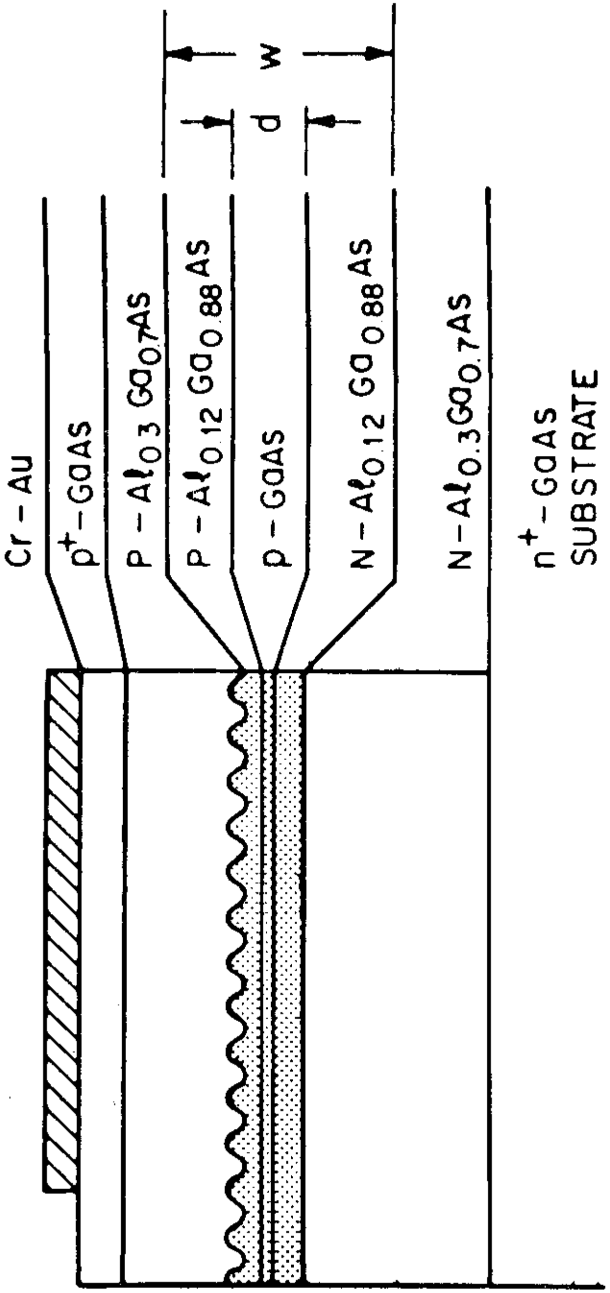

w
d
Cr - AU
p+ - GaAS
P - Al0.3 Ga0.7AS
P - Al0.12 Ga0.88AS
p - GaAS
N - Al0.12 Ga0.88AS
N - Al0.3Ga0.7AS
n+ - GaAS
SUBSTRATE

Fig.17

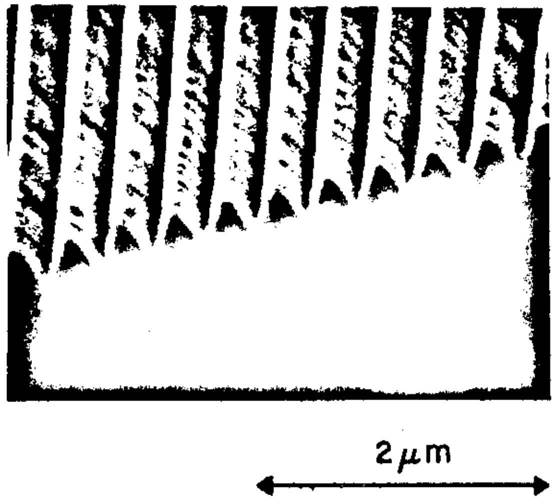

2μm

Fig.18

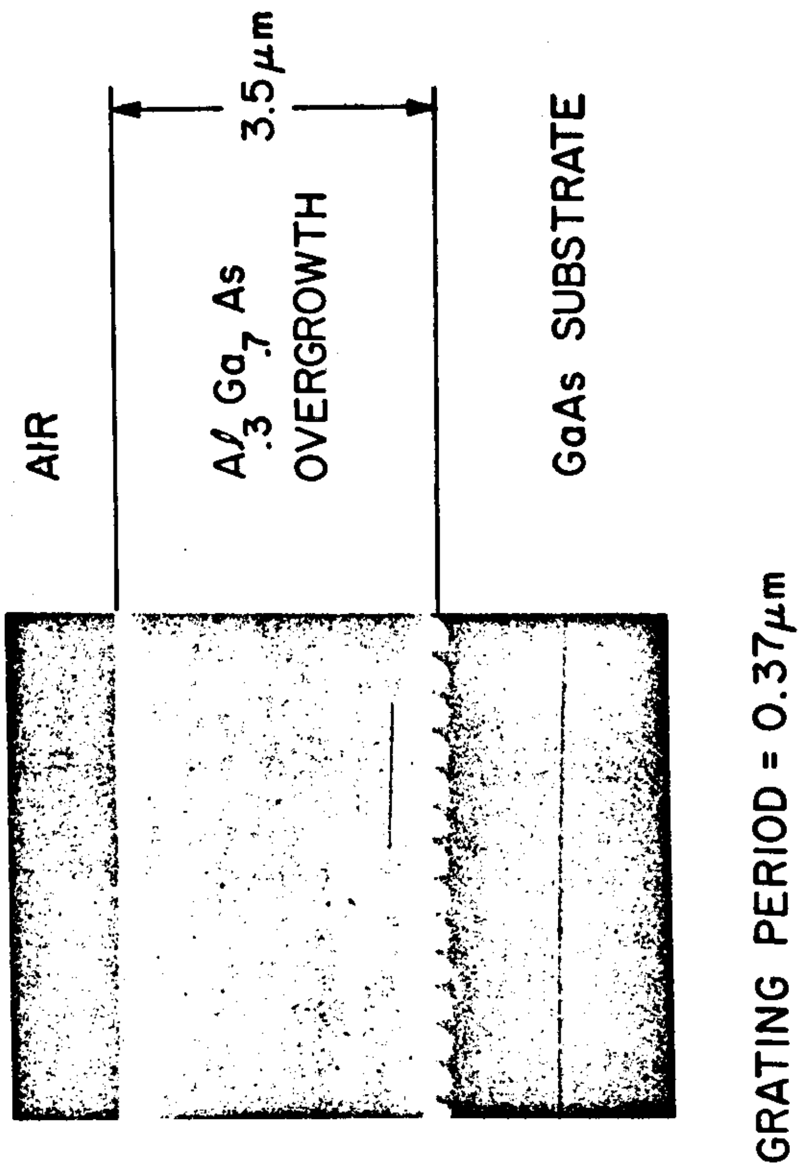

3.5μm
AIR
$Al_{.3}Ga_{.7}As$
OVERGROWTH
GaAs SUBSTRATE
GRATING PERIOD = 0.37μm

Fig.19

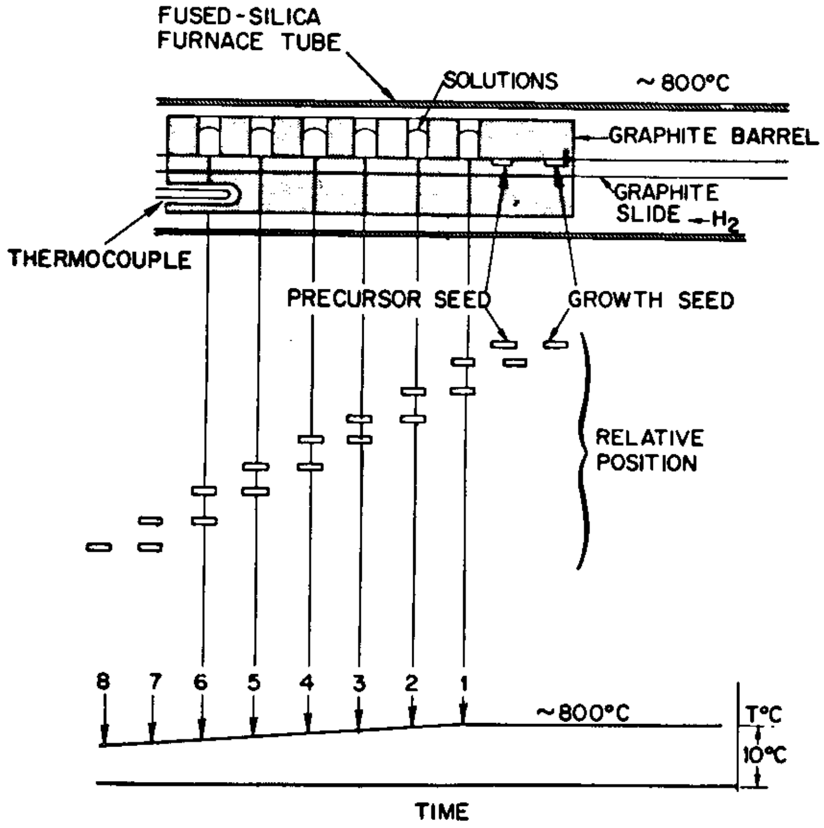
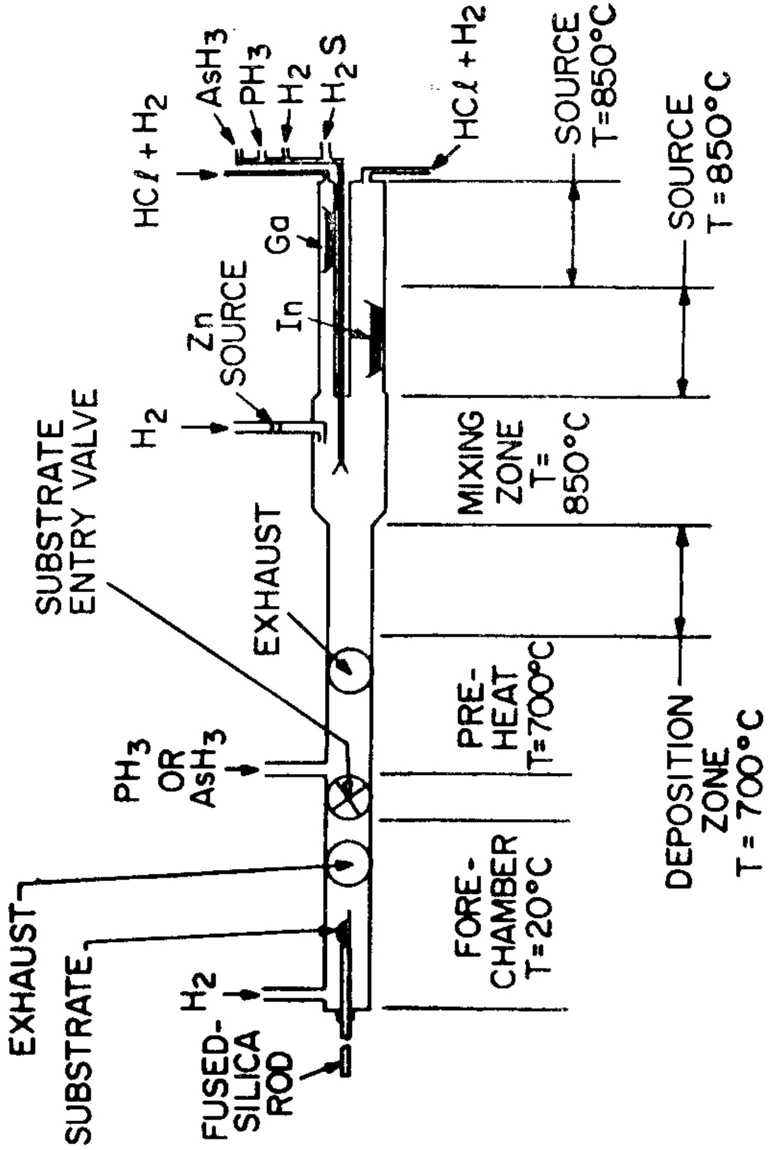
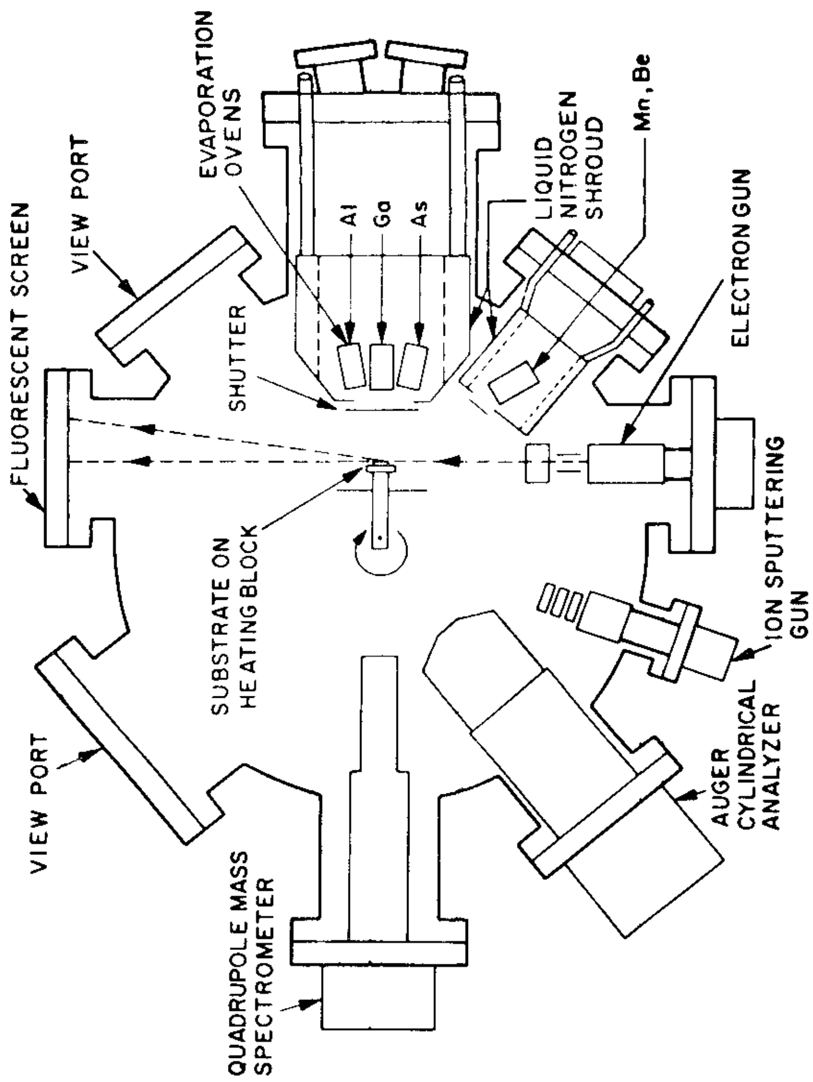

FUSED-SILICA
FURNACE TUBE
SOLUTIONS
~ 800°C
GRAPHITE BARREL
GRAPHITE
SLIDE ← H_2
THERMOCOUPLE
PRECURSOR SEED
GROWTH SEED
RELATIVE
POSITION
8 7 6 5 4 3 2 1
~800°C
T°C
10°C
TIME

Fig.20



$HC\ell + H_2$
AsH_3
PH_3
H_2
H_2S
$HC\ell + H_2$
SOURCE T=850°C
SOURCE T=850°C
Ga
Zn SOURCE
In
H_2
SUBSTRATE ENTRY VALVE
EXHAUST
MIXING ZONE T= 850°C
PRE-HEAT T=700°C
DEPOSITION ZONE T = 700°C
PH_3 OR AsH_3
FORE-CHAMBER T=20°C
EXHAUST
SUBSTRATE
H_2
FUSED-SILICA ROD

Fig.21



EVAPORATION OVENS
Al
Ga
As
LIQUID NITROGEN SHROUD
Mn, Be
VIEW PORT
FLUORESCENT SCREEN
SHUTTER
ELECTRON GUN
SUBSTRATE ON HEATING BLOCK
ION SPUTTERING GUN
VIEW PORT
AUGER CYLINDRICAL ANALYZER
QUADRUPOLE MASS SPECTROMETER

Fig.22

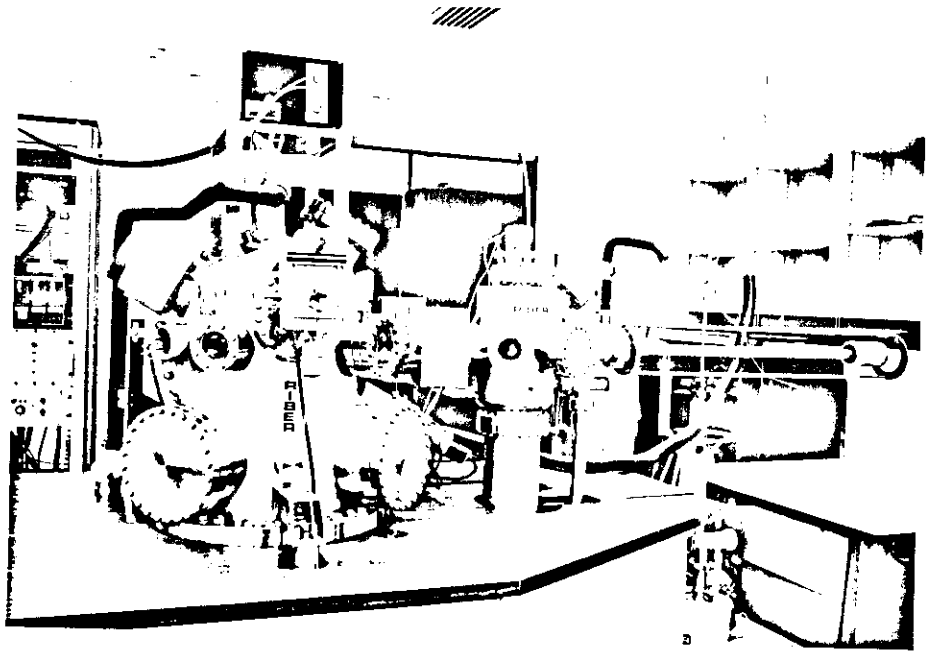


Fig.23

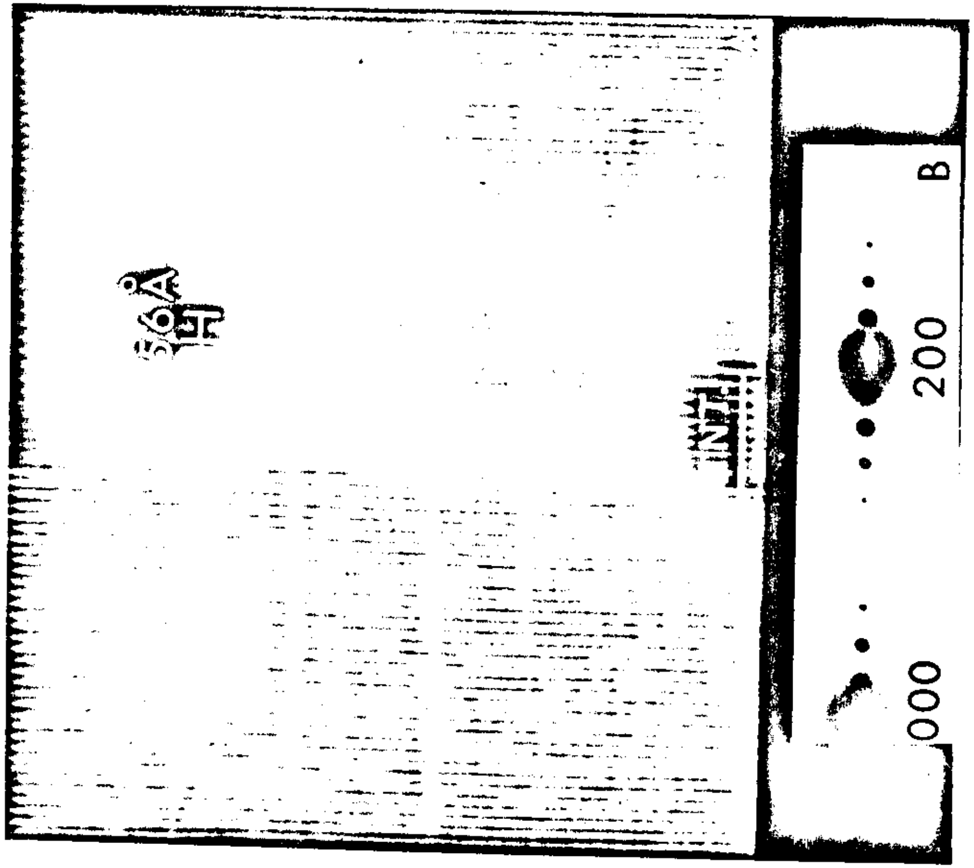


Fig.24

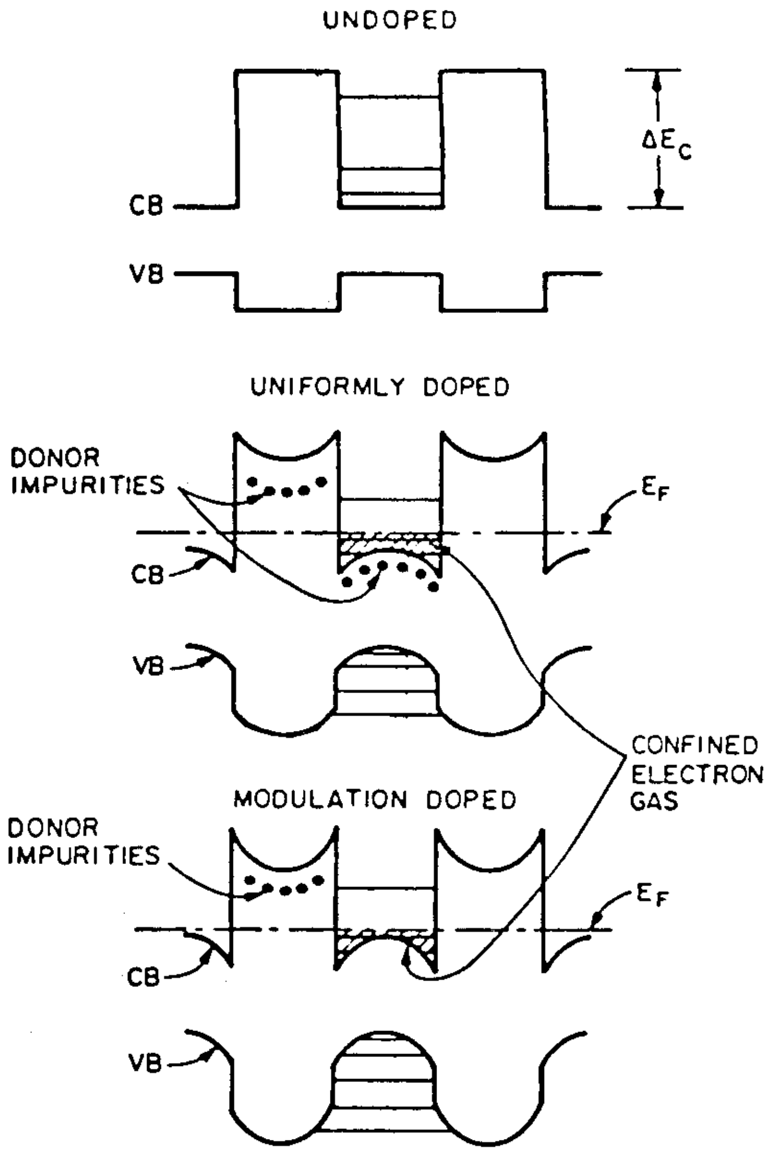

UNDOPED
ΔE$_C$
CB
VB
UNIFORMLY DOPED
DONOR
IMPURITIES
E$_F$
CB
VB
CONFINED
ELECTRON
GAS
MODULATION DOPED
DONOR
IMPURITIES
E$_F$
CB
VB

Fig.25

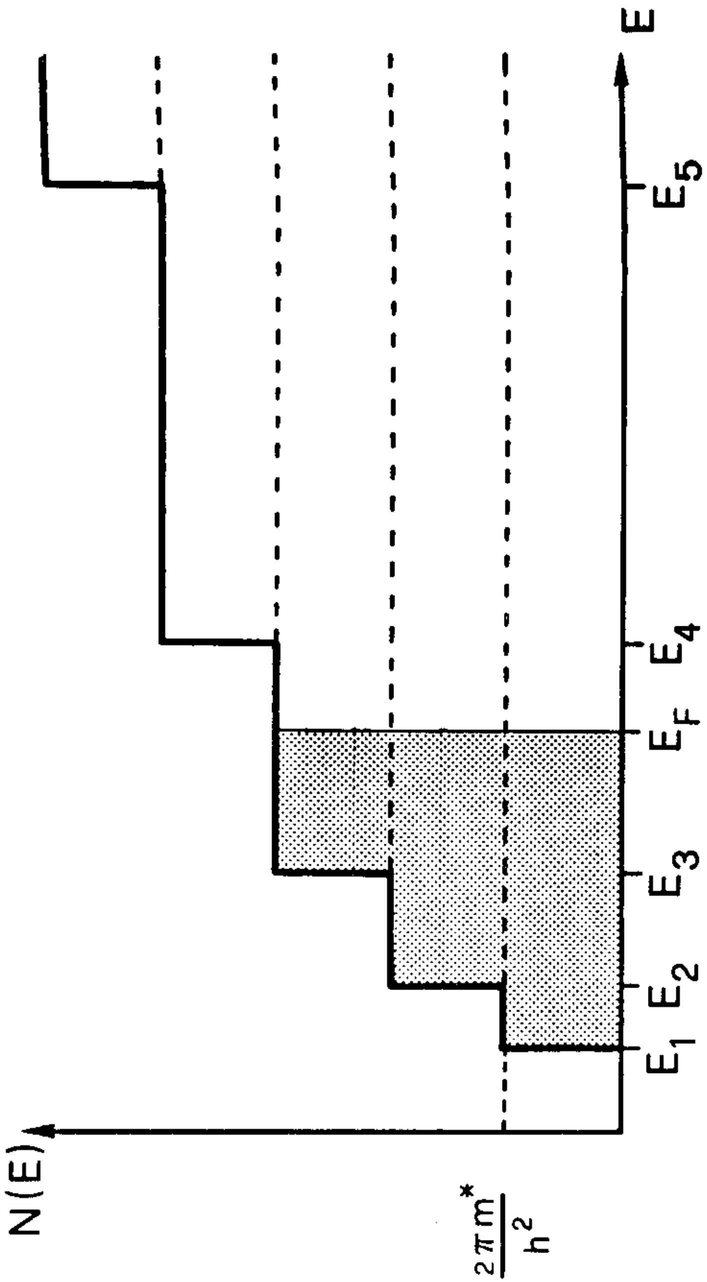

E
E$_5$
E$_4$
E$_F$
E$_3$
E$_2$
E$_1$
N(E)
$\frac{2\pi m^*}{h^2}$

Fig.26

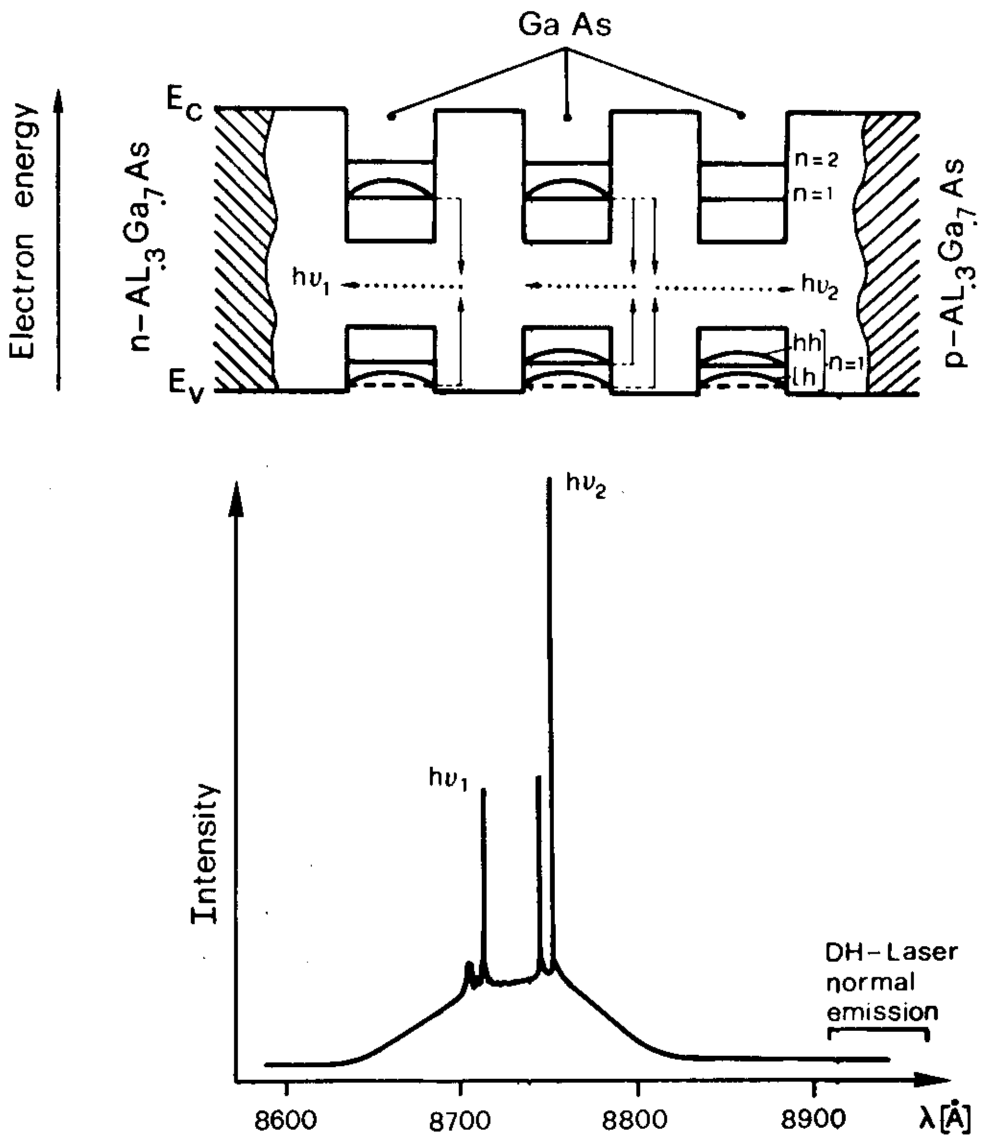

Ga As
Electron energy
E_C
E_V
n-$AL_{.3}Ga_{.7}$As
p-$AL_{.3}Ga_{.7}$As
n=2
n=1
hh
lh
n=1
$h\upsilon_1$
$h\upsilon_2$
Intensity
DH-Laser normal emission
8600
8700
8800
8900
λ[Å]

Fig.27

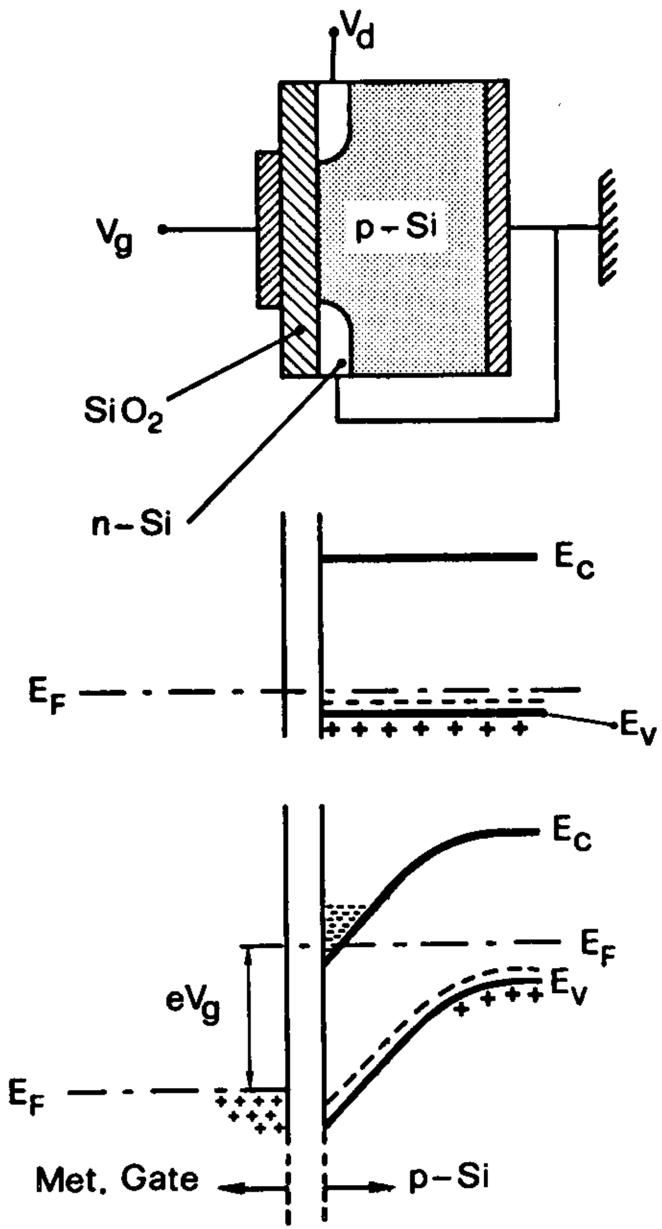

V_d
V_g
p-Si
SiO_2
n-Si
E_C
E_F
E_V
eV_g
Met. Gate
p-Si

Fig.28

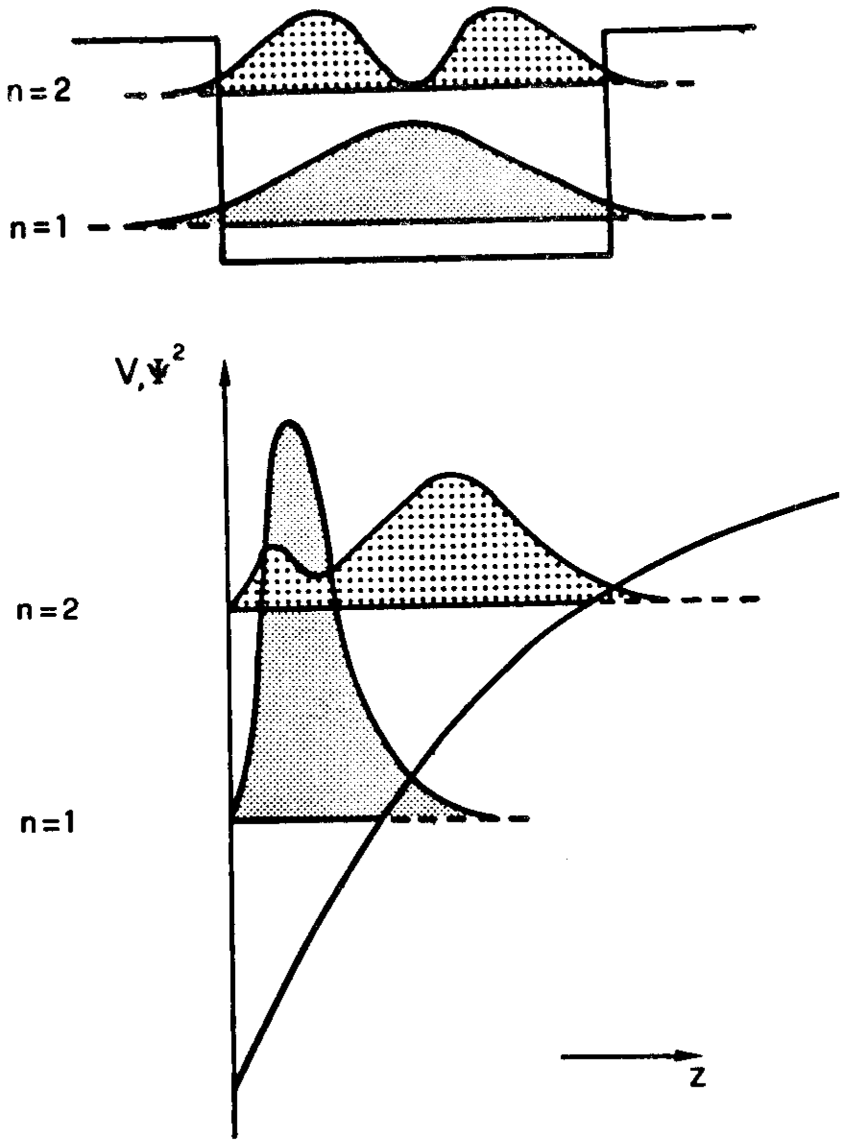

n=2
n=1
V,Ψ²
n=2
n=1
z

Fig.29

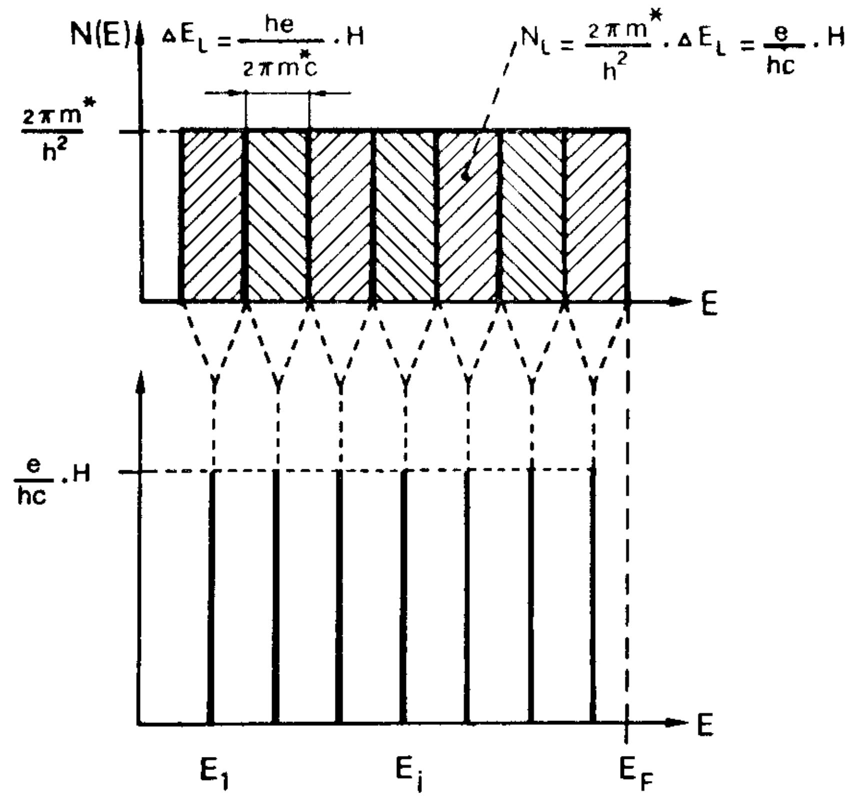

N(E)
ΔE_L = he/(2πm*c) . H
N_L = 2πm*/h² . ΔE_L = e/hc . H
2πm*/h²
E
e/hc . H
E
E_1
E_i
E_F

Fig.31

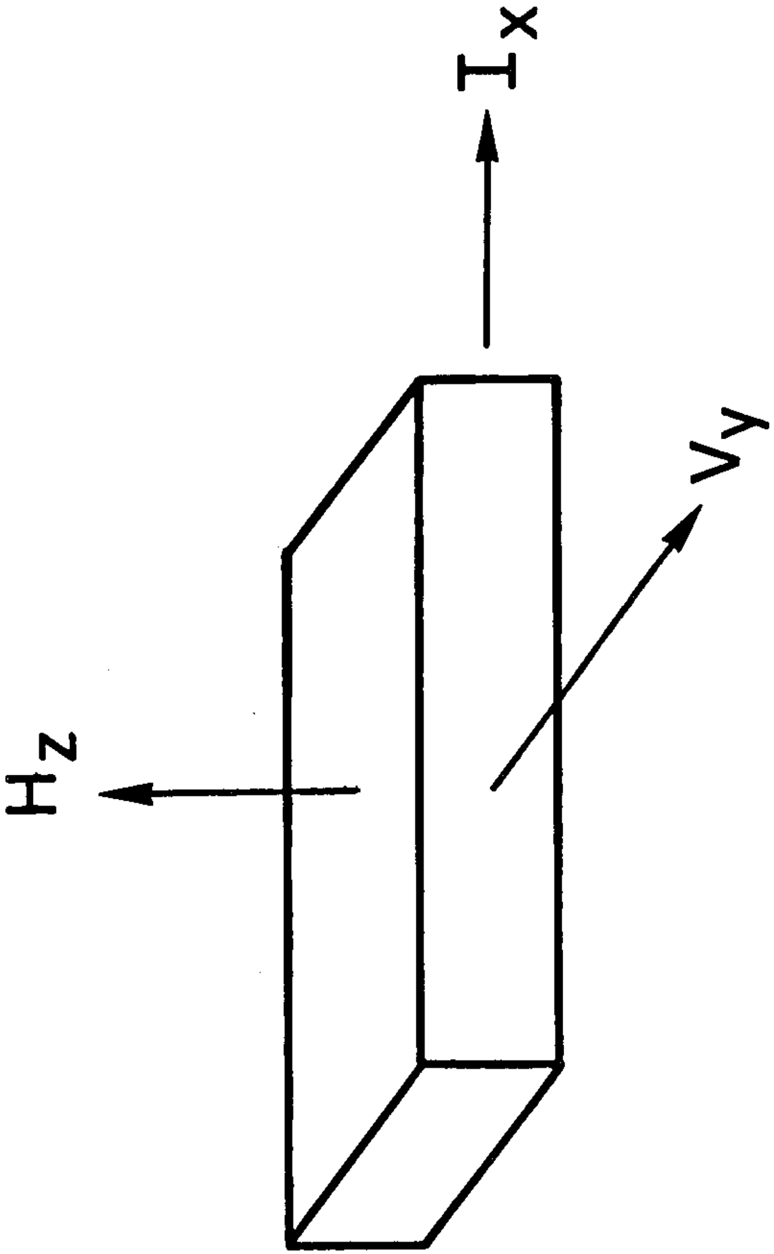


Fig. 31

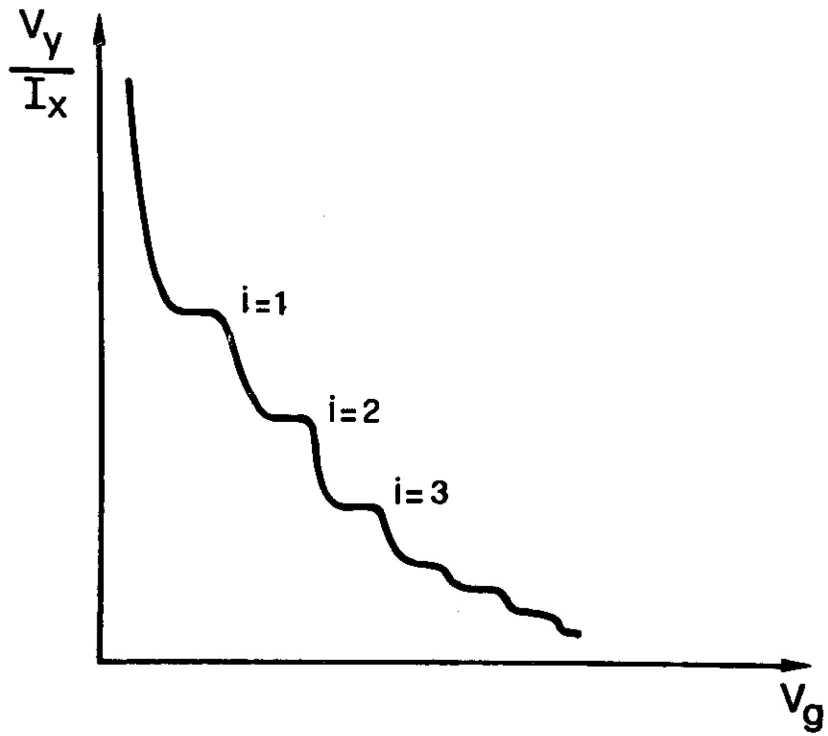


Fig. 32

THE BANTU EDUCATION ACT AND SOUTHERN AFRICA

G.E.Tanyi

The National University of Lesotho, P.O.Roma 180, LESOTHO.

1. The doctrine of apartheid and the Bantu Education Act

The Bantu Education Act which was passed by the government of the Republic of South Africa in 1953 is one of a set of measures designed to strengthen the machinery of "apartheid" - the doctrine of white supremacy of the Republic of South Africa. The object of this act is to deny the South African black all access to the mathematical, scientific and technical education necessary for healthy human development and consequently limit him and his offspring to menial servitude - a role prescribed for him in the blue prints of "apartheid". Only 26 years after its promolgation into law, the Bantu Education Act definitely tipped the balance of the scientific manpower of the Republic of South Africa in favour of its white citizens : 99% of the engineers, 78% of the natural scientists, 91% of the technicians and 72% of the artisan of the Republic of South Africa were whites.

Few people outside Southern Africa understand the mechanics of this act and its implications for the future of black Africa in its entirety. The organizers of this centre have observed the continuous absence of black South African Scientists from its activities since the creation of the centre. The absence of black South African Scientists in the activities of International Scientific institutions of this kind is one result of the Bantu Education Act. It is with the hope of remedying this situation that I have gratefully welcomed this opportunity to explain the Bantu Education Act to the Scientists and Mathematicians of this community.

To give you a clear picture it is necessary to begin by locating the Bantu Education Act in the overall doctrine of apartheid. "Apartheid" is a doctrine of racism, of white supremacy over non-whites, and its tenets are obnoxoius to all rational human beings. I beg your pardon in advance should any of the texts quoted in this presentations offend your better natures.

2. The Bantu Education Act.

It is the irony of our time that the defence of human rights has become unfashionable. Patt Derian, the assistant secretary of state for

human rights in the Carter administration has given a brief but lucid description of the doctrine of apartheid. I quote :

> "With slight alterations in Hitler's concept of a master race and modifications of his "Final Solution" procedures the government of South Africa in 1948 adopted and put into effect a plan to keep all power in white hands...
> ... 14% of the worst land was designated as "homelands" or "reserves" for blacks...
>
> ... (There were) No real South African passports for blacks who received "homeland" assignments. "Homelands" are make-believe "nations" and the South African government expects them to issue passports which no other nation recognizes and respects." [1)]

The Bantu Education Act was proposed by Dr. Henrik Verwoerd in a political manifesto in 1948 :

> "When I have control of native education I will reform it so that equality with Europeans is not for them. ...
>
> ....What is the use of teaching the Bantu child mathematics (and Science) when it cannot use it in practice. This is quite absurd."
>
> - H.K. Verwoerd 1948 [2)]

The Bantu Education Act became law in 1953. Twenty years later the following survey revealed the mechanics of Dr. Verwoerd's design.

A. State Education Expenditure in 1976 in the Republic of South Africa

Whites	:	R700/child
Indians	:	R250/child
Coloureds	:	R198/child
Blacks	:	R 59/child

B. Pupils/teacher ratio in 1976

Whites	:	20 pupils/teacher
Indians	:	27 pupils/teacher
Coloureds	:	30 pupils/teacher
Blacks	:	47 pupils/teacher [2)]

Before examining the effect of the Bantu Education Act on black universities in South Africa it is important to emphasize that the Bantu Education Act was clearly designed to propagate and safeguard the apartheid doctrine of white supremacy and was supported by some other foreign powers who shared the common interest of maintaining the status quo in Southern Africa. Again I quote Dr. Verwoerd, (the architect of the Bantu Education Act) :

> "There is no place for him (the black man) in the European community above the level of certain forms of labour"
>
> - Dr. H. Verwoerd 3.)

This point of view was also shared by Prof. Marcelo Caetan (former professor of the University of Lisbon) when he declared in 1954 that

> "the blacks are to be directed and organized by Europeans... the blacks must be regarded as productive elements organized in an economy directed by whites"
>
> - Marcelo Caetan 3)

3. <u>The effect of the Bantu Education Act on black universities in Southern Africa</u>

Black universities in Southern Africa fall under three categories :

a) Bantustan or tribal universities created by the government of South Africa in established homelands or native reserves;
b) the black universities in the Republic of South Africa which were established before the Bantu Education Act and which do not belong to any stipulated Bantustans (or reserves) and
c) those black universities belonging to black sovereign states which are either completely surrounded by or share a boundary with the Republic of South Africa.

There are 3 universities in the latter category - the National University of Lesotho (which originally served the three nations of Lesotho, Botswana and Swaziland under the name of the University of Botswana, Lesotho and Swaziland), the university College of Botswana and the University College of Swaziland.

The Bantustan Universities isolated from all external intellectual stimulation have been left to degenerate in keeping with the spirit of the Bantu Education Act. Their graduates find it legally impossible to do postgraduate studies outside South Africa or to attend seminars and workshops in international centres such as the I.C.T.P.
The reason is a classic example of Salinger's "catch 22" :

- Since Bantustans are "Nations" they have (and exercise) the right of issuing passports to their citizens.
  Because no other country (except South Africa) recognizes these passports, the Bantustan citizen is unable to leave South Africa where he is confined to his reservation !

The black sovereign states bordering South Africa declared their objection to the Bantu Education Act and withdrew from the common pool of the South African education system creating their own primary, secondary and higher educational structures. Given their weak economies and the continuous destabilizing raids of the Republic of South Africa these universities are finding it difficult to keep their doors open, not to speak of giving their students the scientific and technological education necessary to compete for their existence.

The black universities of the Republic of South Africa continue to carry the full brunt of the Bantu Education Act and the various control laws of the South African ministry of Education. Divorced from both the white and the Bantustan universities, the black university of the Republic of South Africa is constrained to evolve in intellectual isolation.

4. <u>The African dilemma</u>

From Ghana to Chad and from Chad to the Southern tip of Africa the black African university is still fighting for its survival many decades after its creation. African politicians advocate a "transfer" of technology from the developed nations while African Scientists attend international conferences, write papers in learned non-african journals and work in research laboratories in the developed countries. One African state after another has won its political freedom only to create hunger and misery for its unfortunate people. The inability to feed themselves has become the symbol of freedom for many african nations.

This has been the result of freedom movements unaccompanied by parallel scientific and technological movements - of the lack of appropriate measures to ensure future scientific and technological sufficiency. Shall we also allow free Namibia and Azania to follow the root of Ghana and Chad to chaos ?

5. A strategy towards scientific and technological sufficiency

It has now become necessary to take immediate and effective action to stabilize the black African universities in order to permit the developing African states to evolve viable technologies appropriate to their environments. This is the surest and most effective long term means of correcting the damage caused by apartheid policies and decades of colonial and neocolonial brainwashing.

The experience of India, Pakistan, Brazil and other third World nations has revealed that a quick and efficient way of generating science and indeginous technology is through the creation of scientific centres or institutes. For Southern Africa such a centre or institute must be designed not only to pull existing scientists together and provide them with a forum for discussion, research and publication but it must at the same time act as a centre for continuous advanced learning for the many deprived graduate victims of South Africa's Bantu Education Act. Simultaneously it must dedicate itself to research in the modification of existing technologies and the generation of indeginous technologies for the African environment.

I recall that in 1972 a number of Africans (including myself) met here under the auspices of Prof. Abdus Salam to discuss the creation of an African Centre of Advanced Studies. Our failure to see it through and the events of our time have served only to demonstrate the importance and urgency of this venture. I am afraid that unless some urgent action is taken, we shall be overtaken by the growing chaos and instability in today's Africa.

For the many displaced African scientists, the I.C.T.P. has always been and continues to be a haven for work, study and exchange of ideas. I am very grateful to Prof. Abdus Salam, to UNESCO and to the Italian people for making it possible.

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3.) The Herald, Harare, Zimbabwe -26 June 1983.
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ON PROBLEMS OF TEACHING PHYSICS IN RIVERS STATE OF NIGERIA

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ABSTRACT

The present paper reports the problems of teaching physics in Rivers State of Nigeria.

Some suggestions to obtain solutions to these problems are given. It is hoped that by incorporating these suggestions into the educational system, the poor enrolment of students in science in general and physics, in particular at various levels of education, can be improved.

Introduction

Man is the focus of innumerable forces around him. These forces limit his life and comfort. Hence, to improve the quality of our life we are motivated to understand how these forces may be resisted, guided and controlled. The understanding of these natural forces of life is the main object of physics. The guidance and control of these forces leads to the development of technology. Thus, development is the conquest of the Universe through science and technology.

The development of any country, therefore, depends on the direction in which science education in schools, colleges and universities progresses. The developing countries in the world have many problems in this field. This paper is an attempt to review some of these with special reference to the teaching of physics in the "Rivers State of Nigeria".

Preview of the development

The formal educational system in Nigeria is quite young. The first institution of higher learning, "Yaba College" was established in 1932. It is interesting to note that in the year 1960, the "University of Nigeria, Nsukka", the first Nigerian University came into existence. However, the efforts made by by the Government since 1960 for the development of education are commendable. There is an explosive increase in the number of schools and universities since Nigeria became independent. It is worthwhile to mention that at present Nigeria has 13 Federal Universities, 7 Federal Universities of technology, and 6 State Universities, a total of 26 Universities in all. There is also an exponential in the number of primary, secondary, teacher's training colleges and polytechnics. In spite of all this expansion, the quality of education is inadequate. Ideal concepts and ideal systems are far from being realized in practice. Practical systems are never perfect because they suffer from the existence of opposing forces or damping constraints. Hence, aims with which this rapid expansion was made are far from achievable horizons.

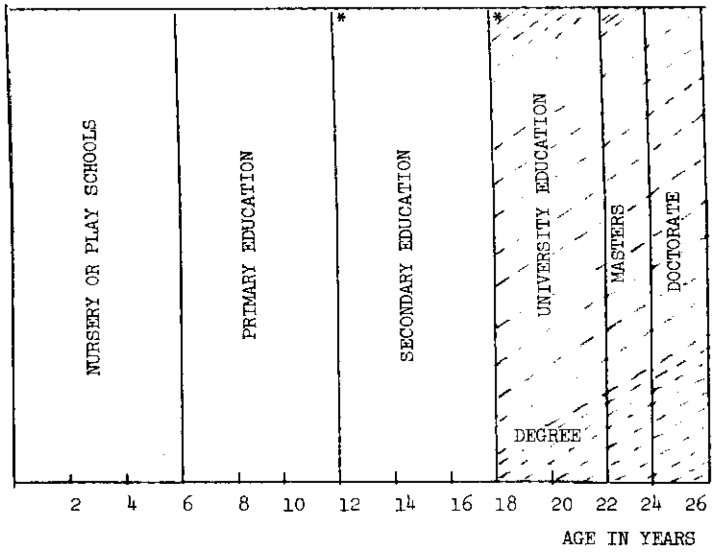
Structure of educational system in Nigeria

Nigeria's philosophy of education is based on the fact that equal educational opportunities for all her citizens will be provided at primary, secondary and university levels. Accordingly, in 1976 the "Universal Primary Education" scheme came into force. Generally speaking primary education is free and has been compulsory since 1979 and all schools are financed by the "Government of Nigeria".

The general pattern of primary education in the country is that the students must start school at the age of six. However, in urban areas many have attended play schools or nursery schools. The aim of primary education is to develop all aspects of the child: physical and emotional as well as intellectual and cultural. Moreover, opportunities are made available for instruction in religion and traditional subjects like history, geography, music, etc. Although mathematics is taught, unfortunately passing in mathematics is not required for promotion to higher classes.

At the end of the primary education, i.e., roughly at the edge of twelve or more students take a common entrance examination at State or Federal level. On the basis of their performance they enter the secondary schools and secondary education lasts for six years. Nowadays, in addition to traditional education, emphasis is placed on professional education in the fields of Electronics, Carpentary, Catering, Smithy, Agriculture and so on. Children entering into the schools have full freedom to choose their careers. During these six years of study students learn English, a foreign language (normally French), social sciences, science subjects or technical subjects. At the end of this period they take examinations conducted by "West African Examination Council", though these do not normally include all the subjects that the students have studied. In fact, a pupil may take an exam in as many, or as few, subjects as is thought suitable.

After secondary education the students appear at the entrance examination conducted by the "Joint Admission and Matriculation Board". The successful candidates, about 10% of the secondary output, is absorbed in the universities. Depending on the background and performance at the "JAMB" examination, the students pursue their university education in either of the faculties viz, Humanities, Law, Science, Engineering, Medicine, Business Administration, etc.. Normally, the University degree programme is for four years. During these years the students concentrate on specialized subjects of their interest. However, they have to earn a credit of about twelve units in the subjects offered by the faculty of foundation studies. It may also be mentioned here that some of the universities in Nigeria offer graduate programmes leading to Masters and Doctorate degree. These programmes vary in their duration and course content from university to university. Moreover, the students who cannot enter into the universities can pursue their higher education in colleges of Science and Technology, colleges of Education, and Polytechnics. The sketch of educational pattern in Nigeria is shown in Fig. 1.



* Common Entrance Exam.

Fig. 1

Education in the Rivers State

To begin with a brief report of educational institutions and enrollment of the students in these institutions in the Rivers State during 1970-1982 is given in Table 1 while Figs. 2(a) and 2(b) indicate graphically the statistics for primary and secondary schools.

Table 2 gives the total staff strength and the percentage of qualified teachers in the 1981-82 session (Fig. 3).

Primary Education

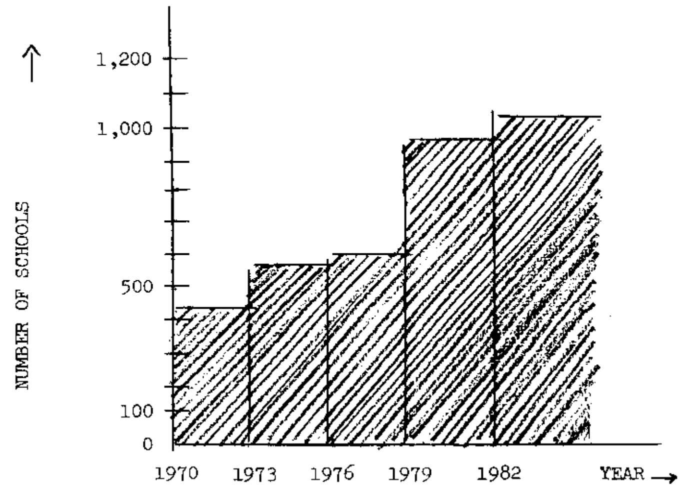


Fig. 2(a)

Secondary education

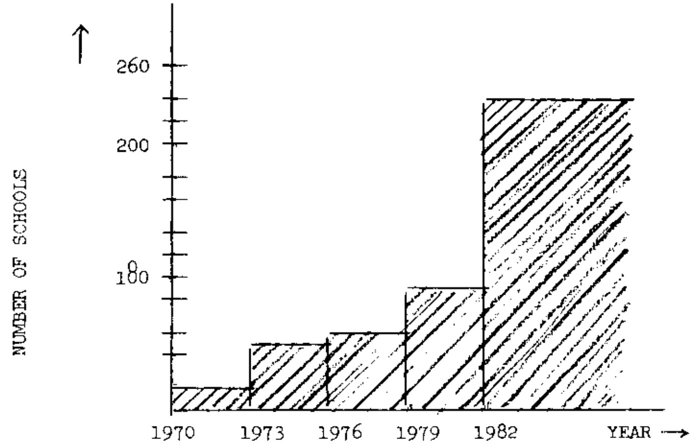


Fig. 2 (b)

Percentage of qualified staff

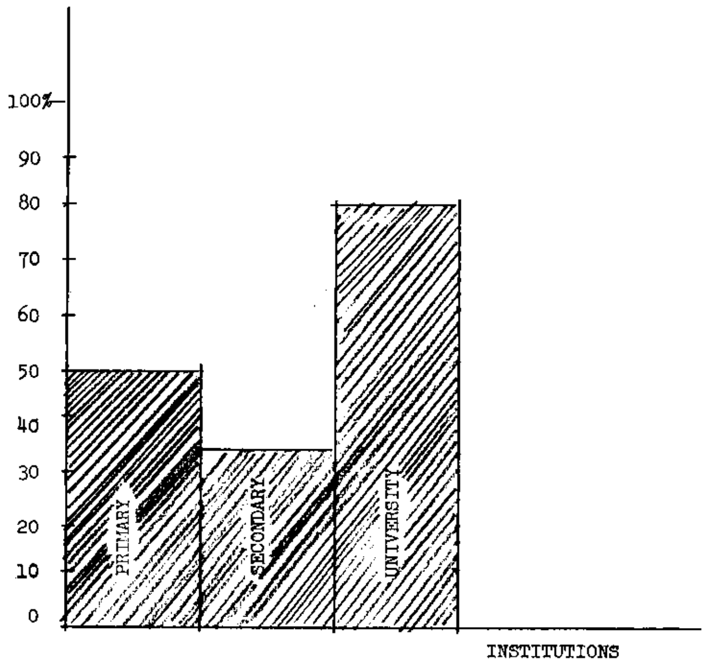


Fig. 3

From Table 1, it is obvious that remarkable progress has been made in terms of a quantitative aspect of education. However, it is common experience that when quantity grows quality deteriorates. But in the field of education, the quantitative increase at the expense of quality cannot be tolerated. Let us, therefore, look into the causes of deterioration of quality of education.

Number of educational institutions and student population

Year	Primary Schools	Secondary Schools	Teachers Training Colleges	Technical Vocational Schools	Institutions of Higher Learning
1970	409	21	3	3	2
Student's Enrolment	151,000	7,632	470	527	218
1973	583	43	7	4	2
Student's Enrolment	173,252	22,680	N.A.	N.A.	589
1976	595	52	7	4	2
Student's Enrolment	275,591	36,780	5,743	3,728	332
1979	924	97	14	5	3
Student's Enrolment	510,488	69,706	10,241	2,418	2,013
1982	1043	234	19	5	3
Student's Enrolment	513,731	92,902	9,153	3,111	6,624

TABLE 1

Teaching staff and percentage of qualified teachers

Year	Primary Schools	Secondary Schools	Teachers Training Colleges	Institutions of Higher Learning
1981	14,304	3,397	312	605
percentage of qualified teachers	50%	32.5%	29.1%	80%

TABLE 2

Primary education is the key point in the development of the child. It is the basis of all educational development. To build a strong nation, this base should be firm like an elephant. Anything can be achieved with a strong base and a strong mind. But, it is worthwhile to note that only 50% of the teacher population employed in primary schools are qualified. Most of them have had no education in Science and Mathematics. It is interesting to note that passing in mathematics is not compulsory for promotion to higher classes. Here's the loop hole in the educational system. It is well known that the scientific speculation has two streams, viz, mathematical describable models and scientific experimentation. Therefore, there is a need to emphasize the importance of mathematics in primary as well as secondary schools.

It is believed that the study of natural science should start at elementary school level. This study should be by direct experience because, when a child learns by direct experience he is motivated to acquire academic and practical skills. Unfortunately, this concept is lacking in the present educational system.

In the post-primary institutions the situation is unbelievable. There is a great shortage of qualified staff. From Table 2, it is clearly seen that only 32.5% of the total teaching staff is qualified. In these schools teachers are not committed to their profession. The lack of dedication, punctuality, motivation etc. is a common phenomena amongst teachers.

However, in institutions of higher learning this situation is greatly improved. More than 80% of the staff is basically qualified.

At this point, I would like to add some of my own observations made during teaching at the freshman's year in the University. It may be mentioned here that physics is a compulsory subject for this class in the faculties of Agriculture, Engineering, Environmental Science, Medicine and Science. Moreover, for gaining admission in some of these faculties the student must earn a "credit" in Physics in the "West African School Certificate examination".

However, I am appalled by the students' ignorance of their natural environment. The students entering in the University cannot

(i) differentiate between a star and a planet although they are well versed with the nursery rhyme, viz, twinkle, twinkle little star.....

(ii) name the different colours observed in a rainbow.

(iii) indicate the direction in which the crescent moon rises and so on.

The lack of familiarity with natural phenomena is an unsurmountable obstacle in science education as well as in rational instruction.

In the physics laboratory they see and use Vernier callipers, screw gauge and other basic equipment for the first time at the University level. Finding of the Vernier constant, plotting of graphs and other basic concepts which they are expected to know at secondary levels have to be taught at the university level.

About 90% of the students offering physics cannot differentiate between a primary cell and secondary cell. They do not know various components and functions of most of the equipment they are supposed to use. It is hard enough for them to make the electrical circuit diagram.

In a class of about 40 to 50 students only one student knows the meaning of isosceles triangle, equilateral triangle, parallelogram, etc., the reason being, geometry is not taught in many schools. Only a few students can correctly define trignometrical functions. Who is to be blamed for the ignorance of these young students - the foundation pillars of the Republic of Nigeria? It is definitely the fault of we teachers engaged in imparting education to the students.

Thus there is a need (i) to evolve a uniform approach of teaching physics, (ii) to have mutual co-operation between primary, post primary and University teaching. The students entering the University must be well prepared to continue their education and have a basic knowledge of the subject in order to study physics.

Another problem of concern is very low (negligible) enrollment in the degree programme with "Physics Major". Table 3, (Fig.4), shows that most of the students opt for engineering and management science subjects. A very few about 7.9 to 9.4% of the total population registered in the university have enrolled in the faculty of science during the last three years, and only a negligible fraction of these have any desire to read physics. A similar trend was observed by other Nigerian Universities as well as by Sierra Leone University. Advancement of science and technology is achieved through solutions of physics problems. Therefore, no nation can achieve greatness and development through scientific progress by neglecting mathematics and physics. It is, therefore, necessary to identify the problems of teaching physics.

Enrolment in the University of Science and Technology during last three years

Faculty	1980-81	1981-82	1982-83
Agriculture	576	598	486
Engineering	614	724	710
Environmental Sciences	337	462	518
Management Science	1,122	976	1,118
Science	274	267	271
Physics	17	17	17
Mathematics	-	2	2

TABLE 3

Pattern of students' enrolment

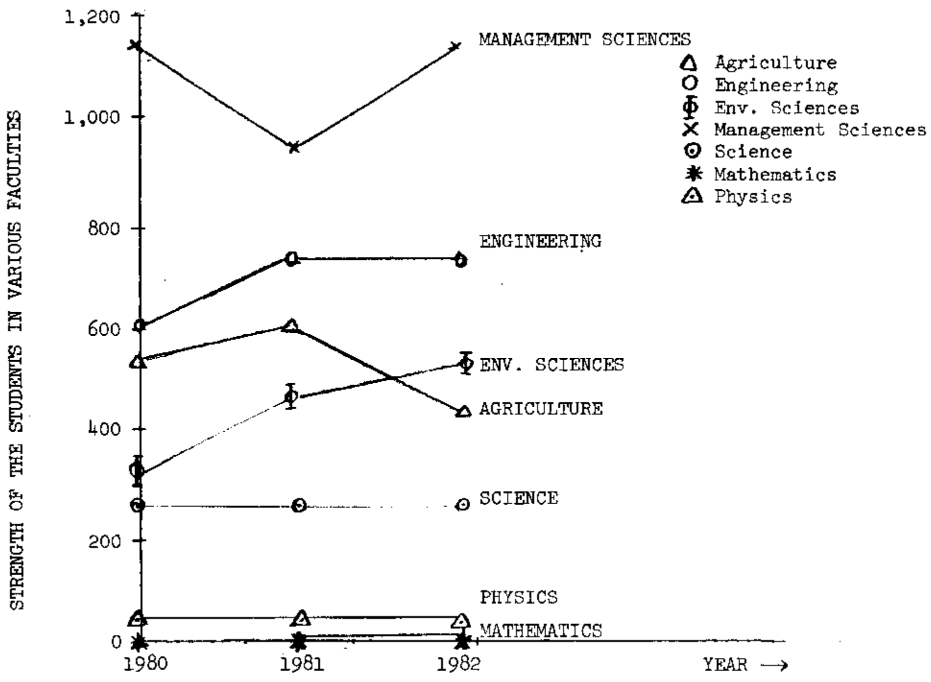


Fig. 4

The problems of teaching physics

(1) It is clear from the above evidence that the students entering the university have a poor background of Mathematics and Physics.

(2) The major problem that faces primary and secondary education is the shortage of qualified teachers. Those who are available have low interest, little commitment and lack of dedication to the teaching profession. The teaching profession is regarded as an unwelcome assignment. Obviously, the quality of teaching is jeopardized.

(3) Physics teachers continue to follow conventional methods of teaching. Their main emphasis is on the completion of the syllabus and preparing students for examinations rather than enhancing comprehension of subject content and motivating students to acquire scientific and technical skills.

(4) The teaching of physics demands laboratories and equipment. These facilities are not available in most of the schools. In some rural areas even teachers of physics are scarce. The reason may be attributed to the fact that the basic amenities of life like continuous supply of water and electricity are not available in rural areas. However, a lot of development is underway and some noticeable changes are visible.

(5) The facilities and skills required to improvise equipment are not being utilized because of a lack of the correct attitude to the profession.

(6) A high proportion of teachers lack confidence and fluency in the subject. They have limited knowledge of physics and its interdisciplinary nature.

(7) The world-wide inflation in every aspect of life has hit the developing countries to a very large extent. The cost of equipment is rising year by year. As a result several essential items required in the laboratories are either not bought or bought in insufficient quantities. Hence, all institutions cannot be adequately supplied with equipment.

Some suggestions for improvement

(1) (a) Teaching in general requires innovation - innovation which is sensitive and responsive to modern trends. Innovation is a gift of few formal thinkers.

(b) To understand physics, requires much abstract thought which only those at a high level of intellect can achieve. Teaching physics requires the ability to put these ideas into practice and this of course, is never easy.

Hence, the experienced teachers having these talents should be encouraged to supervise workshops and seminars of teachers at various levels. This would give the teachers an opportunity to interact with those who have the right talent and correct attitude towards their profession. This will also help the teachers to revise their knowledge of physics, to gain current information of the progress in this field and to prepare new material for teaching.

(2) The students failing in science and mathematics should not be promoted to higher classes.

(3) The basic equipment needed for physics education should be manufactured within the country. Universities proposing projects on improvising equipment should be encouraged and should be given additional financial support. This will help in training the available manpower to acquire skills of fabrication, repair and maintenance of the equipment.

(4) There should be complete co-ordination between primary, secondary and university education. The aim of this co-ordination should be to evolve a uniform and continuous method of teaching.

(5) The problem of rural education can be solved by having mobile laboratories. These should be equipped with audio-visual aids, demonstrations, experiments, books and other scientific equipment, These laboratories along with the qualified teachers should tour the areas with inadequate facilities.

(6) Television, Radio and Press Compaign is needed for public enlightenment on career guidance, job opportunities and attractive careers available to physics graduates.

(7) University teachers should be used to teach in secondary schools during their long vacation. This will help to remedy the poor background of the students in the subject. It is of interest to mention that Rivers State University of Science and Technology, Port-Harcourt, has embarked on this project under the auspicious of "Science Education Centre".

(8) There should be a qualitative improvement in the conditions of service of the teaching profession.

(9) All students opting for physics as a major subject at university level should automatically have free education, free lodging-boarding and free books.

Conclusions

The study of nature plays an important role in the multifarious development of the child's activity. Hence to motivate the child in acquiring academic and practical skills, this study should be by direct experience.

There should be uniform and continuous approach of teaching physics starting from primary level.

To acquaint teachers with the present state of art and knowledge in the field of physics, workshops and seminars should be organized.

Physics should not be taught by reading, recitation and manipulation of black boxes.

New methods of teaching which are sensitive and responsive to modern trends of development should be evolved. These methods should open a limitless field for fabrication and manipulation of scientific equipment. Educational institutions should serve as a powerful mechanism for a generation of indigeneous technology to set into action creative and innovative capabilities of students for the solutions of their problems in life.

Acknowledgements

I wish to thank Dr. H.U. Emereole of RSUST for fruitful discussions. I acknowledge my sincere thanks to Prof. T.T. Isoun, Vice-Chancellor of the University and Prof. S.D. Bajpai, Dean, Faculty of Science for their co-operation and support.

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SOME OBSERVATIONS ABOUT PAKISTAN'S ECONOMY AND SCIENCE

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The purpose of the article is to review the present state of education and scientific development in Pakistan vis-à-vis its present state of economy, with the help of available statistical data.

Pakistan is located in Southern Asia and is bounded by Afghanistan and Soviet Union (north), by China (northeast), by India (east and south-east), by the Arabian Sea (south) and by Iran (west). A simplified map of the country is given in Fig. 1. Pakistan won its independence from the British on 14th August, 1947. Its present population is 83,8 million and has an area of 796,000 square kilometers. This corresponds to an average population density of 105 persons per square km to be compared with the world average density of 33 persons/sq.km and the Asian average of 93 persons/sq.km. Pakistan, therefore, is the 12th densest country in Asia and 38th in the world. The densest country in the world is Hong Kong with a density of 4850 persons/km^2. During the period 1975-81, Pakistan's annual population growth rate was estimated to be about 2.8%. The present adult literacy rate in Pakistan is about 24% as compared with the figures of 36% and 66% for India and China, respectively. The literacy rate among the male population is 30.2% , and in the female population 11.6%. The percentage of school going children in the age group of 7 - 11 years in 64% which is less than the developing countries average of 68%, the reasons for such a low figure being primarily the lesser number of schools, specially in the rural areas where the literacy rate is only 14.3% compared to the urban figure of 41.5%. The situation with regards to enrolment in the middle and high schools (age group 12-18 years) is much worse. Pakistan's figure in this age group is 9% which is miserably low compared with the developing countries average

of 39% and the developed countries average of 64%. For the age group 19-23 years, the enrolment is 3 percent for Pakistan, 13% for the developing countries and 46% for the developed world.

Now we give a few basic figures regarding the economy of Pakistan. The Gross National Product of Pakistan is about $ 30.6 billion at the current market rate. The agriculture sector contributes 29% to the GNP whereas the industrial contribution is about 23%. Table 1 gives the changing trends of the sectorial distribution for Pakistan and India over the years

TABLE 1

DISTRIBUTION OF GNP (Percent)					
	AGRICULTURE			INDUSTRY	
Year / Country	1960	1977	1982	1960	1977
PAKISTAN	46%	33%	29%	16%	23%
INDIA	50%	37%		20%	25%

Pakistan's per capita income is $ 289 compared to India's $ 230, China's $ 281 and that of the USA $ 11,319. The average growth rate of GNP/Capita and the rate of inflation is shown in Table 2.

TABLE 2

	GNP/capita	Av. Ann.Growth rate	Av. Inflation Rate	
Year / Country	1977	1970- 77	1960-70	1970-77
PAKISTAN	$ 190	3.0 %	3.3 %	15.2 %
INDIA	$ 150	1.3 %	6.9 %	8.9 %

The growth rate for the period 1977-81 is estimated to be about 6.1%. The major causes for the high inflation rate during the period 1970-77 were the massive devaluation of Pakistan's currency (1972) and the colossal increase in the rate of remittances by Pakistans working abroad. The home remittances rose sharply from a meagre figure of $ 123.77 million in the year 1972-73 to a fabulous figure of $ 224.94 million in 1981-82, showing a jump by a factor of 18 in a decade. These remittances in turn have led to major socio-economic repercussion on the society in general and has also drastically affected the pace of progress in the realm of education and science.

As far as external trade is concerned, for the year 1980-81 the import bill was $ 5.3 billion vs.a total export of $ 2.9 billion, showing a huge trade deficit of $ 2.4 billion. This deficit is mainly met from home remittances of Pakistanis abroad, which amounts to $ 2.1 billion for the year 1980-81. The corresponding figures for the year 81-82 are $ 2.23 billion from home remittances vs.about $ 2.3 billion from export. Region wise distribution of home remittances is given in Table 3.

TABLE 3

Region/country	TOTAL REMITTANCES (1981-82)	% age of total remittances
Middle East	$ 1.835 billion	82.55
U.K.	$ .121 "	5.44
U.S.	$ .072 "	3.24
Others	$ .195 "	8.77
TOTAL	$ 2.223 "	

Thus Pakistan is a unique country in the world, whose total earnings from manpower export almost equals the total receipts from export of all other commodities The former has also led to adoption of a very liberal import policy by the Government. Among the imports, the biggest single item is oil which is costing Pakistan about $ 1.52 billion annually. The oil import from Saudi Arabia alone is worth .68 billion dollars which is the biggest import from any one country. It is curious to remark that the biggest chunk (~60 %) of the total remittances also comes from Saudi Arabia. The vital role of S. Arabia in the economy of Pakistan is very much apparent from these figures. In terms of manpower responsible for the remittances, unofficial estimates put the figure at about 2 million, mostly working in the gulf states and the middle east, those working in Saudi Arabia alone ranging from about 400,000 to 500,000. Official figures regarding the year wise emigration of labour are given in Table 4.

TABLE 4

Year	Labour Emigration in the year
1971	3,534
1975	23,077
1976	41,690
1977	140,445
1978	129,533
1979	118,259
1980	133,397
1981	153,081

Higher Education

At the time of independence (1947), Pakistan had only two universities. This number has now risen to 19, out of which 10 are general universities and seven are professional (4 Engineering and 3 Agriculture). Two remaining universities have special character - one being an open university and the other is devoted to Islamic studies and is run in close collaboration with Saudi Arabia. The enrolment in the Universities has risen from 5,084 in 1960-61 to 56,705 in 1981-82, an increase by a factor of 11 in the two decades. The corresponding figures for the professional colleges are 12,921 in 1960-61 vs. 82,496 in 1981-82. The enrolment in the general Arts and Science colleges rose from 71,000 (1960-61) to 245,000 (1981-82).

The university enrolment curve shows a slow and smooth increase upto the year 1976, after which we find a steep increase between years 1977 and 1978, followed by a rapid decline in the year 1979 and 1980. This anomalous behaviour is apparently due to technicalities such as overlap of semesters, delay in exams etc. The curves regarding number of educational institutions, their enrolments and output are given in Figs.(2-7). Although the enrolment and output at the Bachelor's and Master's level has been steadily increasing over the years, the output in sciences definitely shows a rapid decrease. The figures in Table 5 highlight this trend

TABLE 5

Year	Output of bachelors and masters in sciences
1974 - 75	13,955
1978 - 79	10,135
1979 - 80	7,598

The Table shows a decrease of about 45 % in the total number of graduates, professional graduates and masters in all sciences over a period of 5 years. The subdivision of the total output for the year 1978-79 is given as follows

Science graduates	4,088	
M. Sc.	1,796	
M. Phil.	100	
Ph. D	9	
Engineering graduates	1,565	
Medical "	1,971	
Agriculture "	606	
TOTAL	10,135	for the year 1978.

Although we do not have complete data of the output of students at the F. Sc. level, the figures available for the years 1972-74 show a

decrease in the number of F. Sc's produced in the pre-engineering group, a fraction of which takes up basic sciences as their career. The output of F. Sc's in the pre-medical group, however, does show an increase in the said period. The details are given in Table 6.

TABLE 6

Category	Year	N° of F.Sc's produced
Pre-Engineering	1972	8,622
	1973	8,521
	1974	6,558
Pre-Medical	1972	9,080
	1973	10,771
	1974	11,560

The rapidly decreasing trend in the output of science students at almost all levels, in very alarming for the development of science in the country. The statistics show that the output of professional graduates (medical, engineering etc.)over the years is steadily increasing which implies, for basic sciences, a percentage decrease even higher than 45 %. It seems that students are, generally, turning away from basic sciences and going over to social sciences. For instance the number of law graduates has risen more than 4-fold during the years 1975-1981. The main cause of this diversion seems due to lack of competitiveness on the part of scientific professions vis-a-vis others. For instance in Table 7 we give the annual salary of a fresh Ph.D in Pakistan in the years 1970 and 1982 and its equivalence in term of various commodities.

TABLE 7

	ANNUAL SALARY OF A FRESH PH.D IN PAKISTAN		GAIN/REDUCTION FACTOR
Year / Equivalence	1970	1982	
PAK RS	9,600	20,400	2
LAND	685.7 sq.yd.	81.6 sq.yd.	1/8
Car (1200 cc)	0.5 car	0.17 car	1/3
PETROL			1/3
WHEAT FLOUR	13 tons	10 tons	

The Table signifies a much greater depletion of the effective salary of an average scientist in Pakistan, over the years than that implied by the official inflation rate of 15 %. On the other hand, incomes in other professions like law, medicine etc. are relatively less effected by the inflationary trends.

SCIENCE AND TECHNOLOGY ESTABLISHMENTS

According to the statistics supplied by the National Science Council of Pakistan, the number of Science and Technology (S & T) establishments in Pakistan rose from 73 in 1974 to 137 in the year 1982. In addition to these S & T establishments, there are at present 19 Universities in the Country. The manpower is these establishments is given in Table 7

TABLE 7*

Year	N° of Scientific Establ.	Manpower		Ph.D/Estab
		Ph.D	M.Sc	
1974	73(S&T ESTAB)+8 Universities	645	1989	7.96
1982	137(S&T ESTAB)+9 Universities	843	3184	5.40

* In the above table and in all the subsequent analysis, we exclude the scientific manpower from Pakistan Atomic Energy Commission, for which no figures are listed in the latest manpower directory published by National Science Council of Pakistan.

The number of S&T establishments in the country has increased by about 88 % in 8 years, whereas the Ph. D manpower increase is 30 % bringing the average number of Ph. D's per institute down for a figure of 7.96 in 1974 to 5.40 in 1982. Most of the above Ph. D's are, however, concentrated only in a few establishments as listed in Table 8.

TABLE 8

PH. D's IN AN S&T ESTAB.	N° OF ESTABL.
0	66
1	25
2	19
3	8
4	1
6	3
16 (PCSIR, Peshawar)	1
31 (PARC, Islamabad)	1
41 (PCSIR, Karachi)	1
49 (PCSIR, Lahore)	1
Unknown	11
Total EST.	137 Total Ph. D's = 246

Compared with these figures, the estimated number of Ph. D's in sciences in the Universities is about 600. The total Ph. D population in the entire country is therefore about 846 (PAEC excluded).

The mushroom growth of institutions in the country in the absence of adequate manpower, particularly at the Ph. D level, signifies an over-all dilution of the scientific effort in the country. Out of 137 institutions listed above, one hundred and nineteen establishments have less

than four Ph. D's and are, on the basis of the meagre manpower alone, not in a position to make any significant contribution towards research and development. The declining trends in the overall scientific output of the country is manifested in Fig. 8 which gives the number of scientific authors publishing each year over the period 1973-77. Pakistan is the only country which shows a downward trend in this figure. The three major establishments with Ph. D strength 16, 41 and 49 are research laboratories of the same establishment i.e. Pakistan Council of Scientific and Industrial Research (PCSIR) located at different places in the country. The other major establishment with 31 Ph. D's is the Pakistan Agricultural Research Council.

Unfortunately, most of the attempts in the past have laid an emphasis on creating more and more institutions rather than initiating a national programme for systematic and sustained production of manpower over the years. We believe that had even a small fraction of the total budget of these establishments which runs into millions of dollars and which has mainly gone into construction of building and the setting up of the administrative infrastructure, been utilized for the manpower production in various scientific disciplines, the state of sciences today would have been different altogether . Rough estimates indicate that the total budget of these S & T establishments is of the order of 72 millions dollars (0.25 % of GNP). The approximate cost of sending one hundred trainees abroad for Ph. D programme does not exceed one million dollars a year which is less than 1.5 % of the total S & T budget. A similar training programme at home institutions/universities shall of course, cost considerably less. We therefore believe that even within the present budgetary constraints the manpower production programme can be successfully implemented if given proper emphasis in our planning.

Another important aspect which deserves attention is the state of affairs in the Universities vis-a-vis S & T establishments compared to 246 Ph. D's in the S & T establishments, the 19 Universities have approximately 600 Ph. D's on their roles which become roughly 70 % of the total Ph. D manpower in the country. But the share of S & T budget allocated to the Universities is ~5 % which signifies a strong mismatch of manpower and

funds. A possible way out may be to initiate a programme for collaboration and co-operation and even affiliation of some of the research establishments with the Universities or the newly established centres of excellence in the country.

The overall scientific manpower in the country is very small. Young people do not find scientific professions attractive at all. Fewer and fewer students are now seeking admission in hard sciences like physics, mathematics and chemistry. The situation in physics is particularly bad. In all the universities of Pakistan, the number of physics teachers is not more than 120 out of which only 53 are Ph. D's. Most of these Ph. D's are concentrated in three to four Universities, leaving the rest without adequately trained staff. The student enrolment in physics is also very poor, the annual output of Masters for all the universities being 250 approximately.

To conclude, it is evident that the pace of progress in science and technology is very slow. Pakistan needs to revitalize its S & T programme so as to accelerate its progress. Indeed it needs to achieve a quantum jump in order to fill the technological gap it experiences today. Needless to say that this would be possible only through a firm commitment on the part of the Government to the advancement of science. While no new institutions or universities be opened, the existing ones must be strengthened. Arrangements for cooperation and collaboration between the S & T establishments and the universities must be institutionalized. To generate manpower in order to meet the growing needs of science and technology, a fresh and rigorous programme should be undertaken for training scientists both at home institutions and abroad . Incentives must be given to attract talented men to scientific professions. A programme of this nature initiated in the late fifties and continued through the sixties by the PAEC and was quite successful in giving science a respectable status in the country. A similar effort is long overdue and is very much in order today.

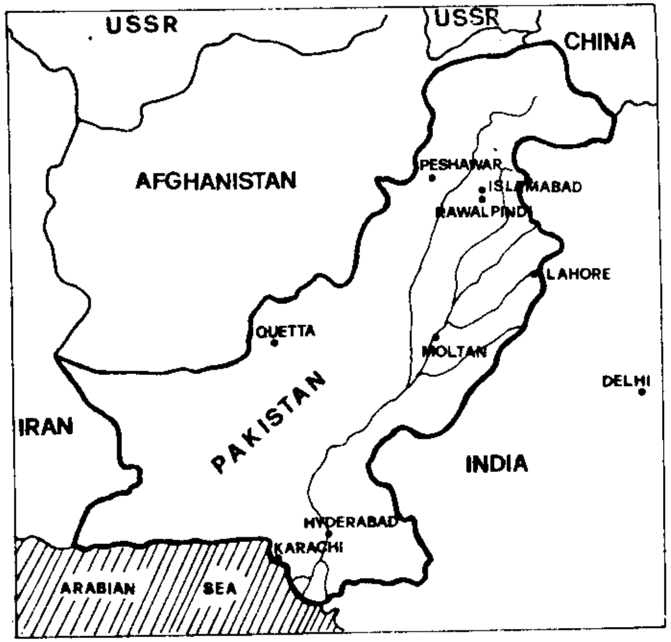
USSR
USSR
CHINA
AFGHANISTAN
PESHAWAR
ISLAMABAD
RAWALPINDI
LAHORE
QUETTA
MOLTAN
DELHI
IRAN
PAKISTAN
INDIA
HYDERABAD
KARACHI
ARABIAN
SEA

Fig.1

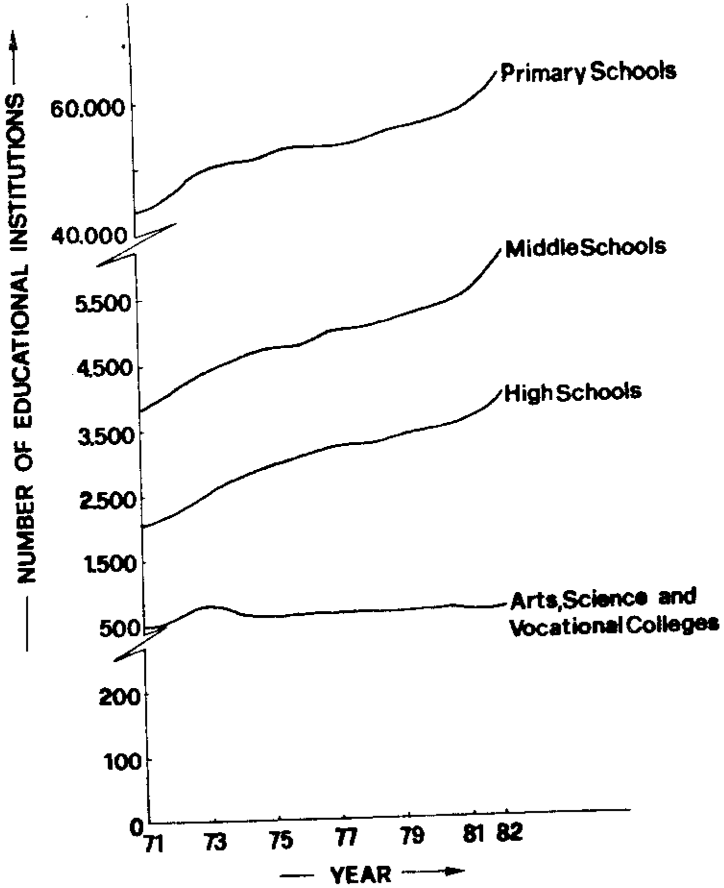
NUMBER OF EDUCATIONAL INSTITUTIONS
60,000
40,000
5,500
4,500
3,500
2,500
1,500
500
200
100
0
Primary Schools
Middle Schools
High Schools
Arts,Science and
Vocational Colleges
71
73
75
77
79
81
82
YEAR

Fig.2

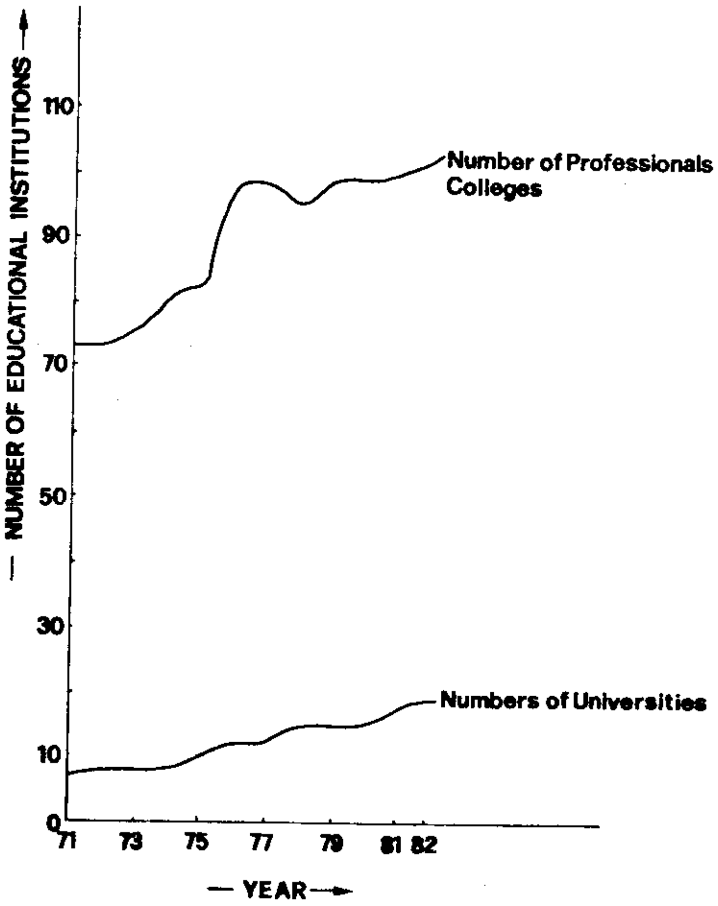
NUMBER OF EDUCATIONAL INSTITUTIONS
110
90
70
50
30
10
0
Number of Professionals Colleges
Numbers of Universities
71 73 75 77 79 81 82
YEAR

Fig.3

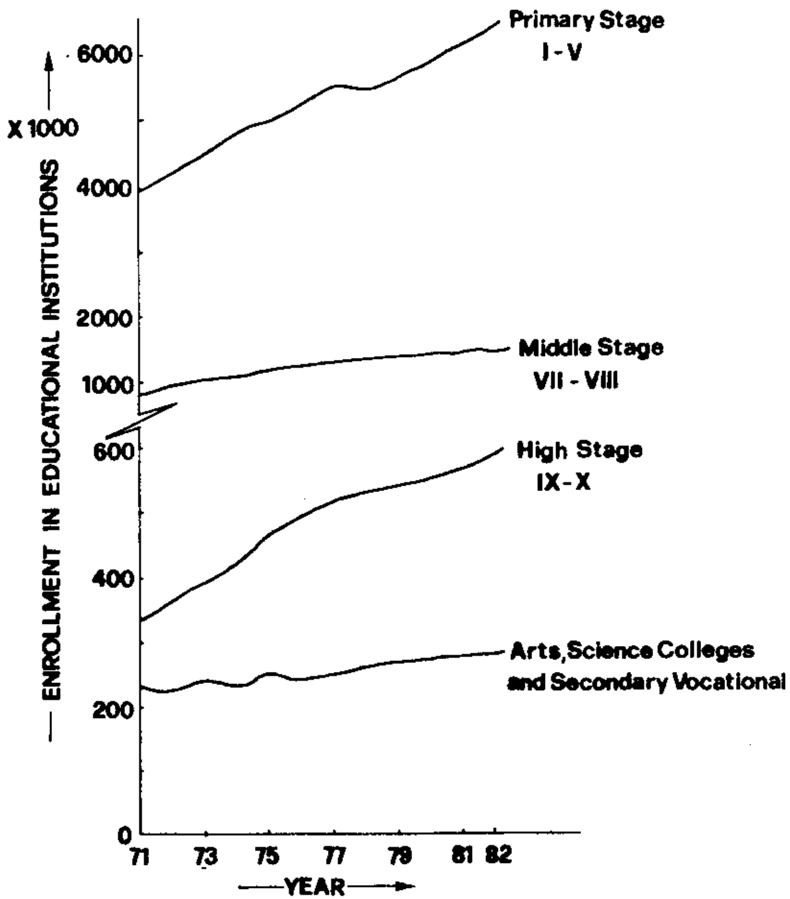
ENROLLMENT IN EDUCATIONAL INSTITUTIONS
X 1000
6000
4000
2000
1000
600
400
200
0
Primary Stage
I - V
Middle Stage
VII - VIII
High Stage
IX - X
Arts, Science Colleges
and Secondary Vocational
71 73 75 77 79 81 82
YEAR

Fig.4

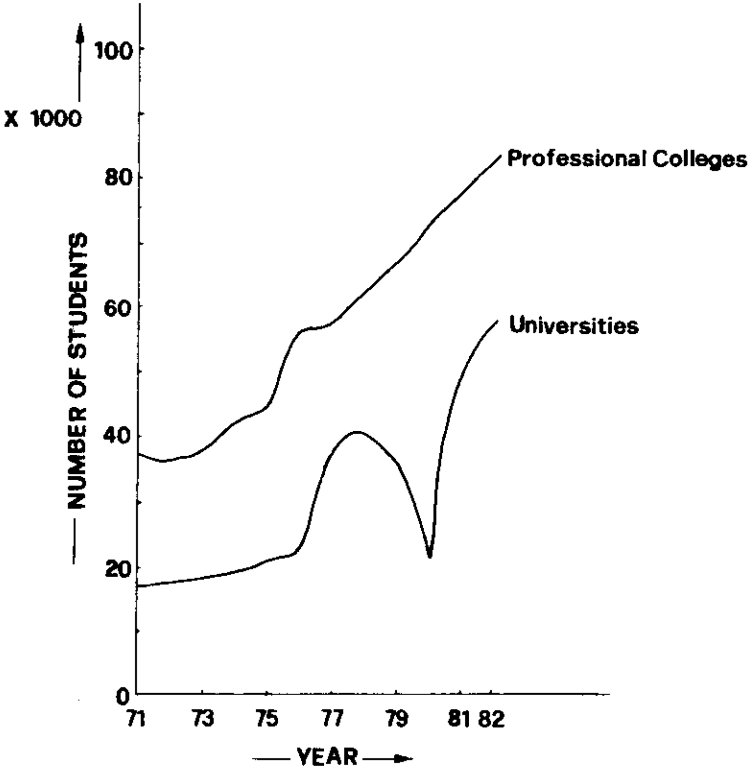
X 1000
100
80
60
40
20
0
NUMBER OF STUDENTS
Professional Colleges
Universities
71
73
75
77
79
81 82
YEAR

Fig.

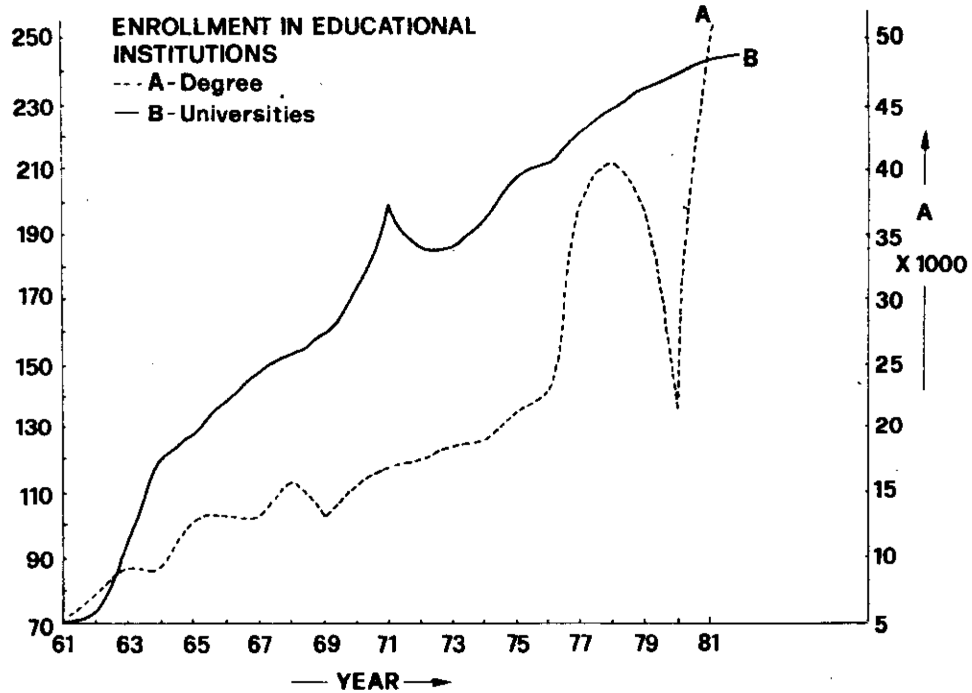
ENROLLMENT IN EDUCATIONAL INSTITUTIONS
--- A-Degree
— B-Universities
A
B
250
230
210
190
170
150
130
110
90
70
50
45
40
35
30
25
20
15
10
5
A
X 1000
61
63
65
67
69
71
73
75
77
79
81
YEAR

Fig.

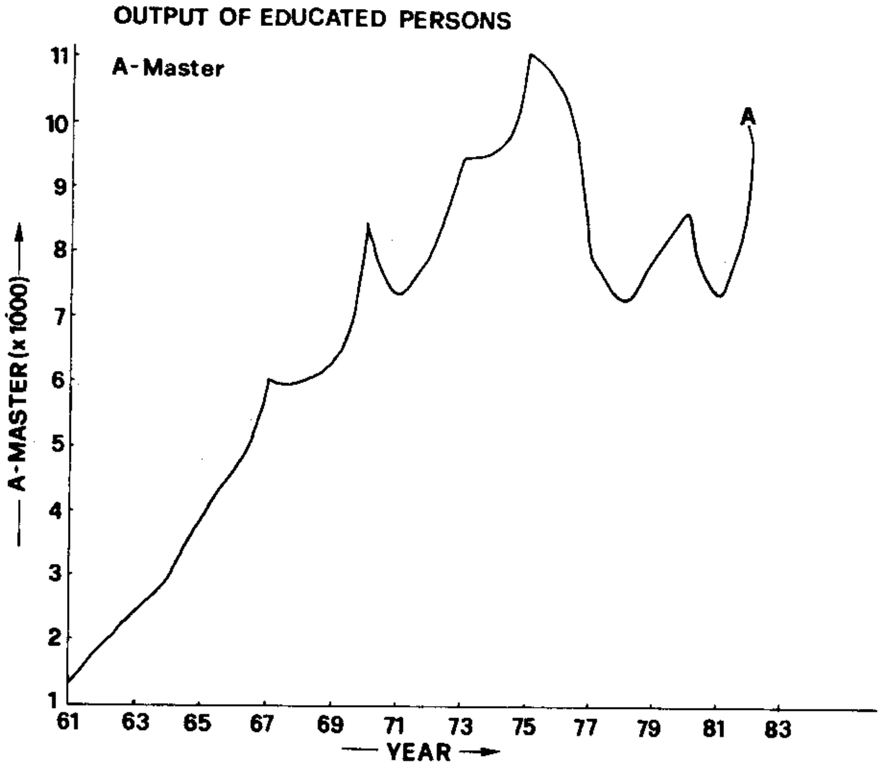
OUTPUT OF EDUCATED PERSONS
A-Master
A
A-MASTER (x 1000)
YEAR
1
2
3
4
5
6
7
8
9
10
11
61
63
65
67
69
71
73
75
77
79
81
83

Fig.7

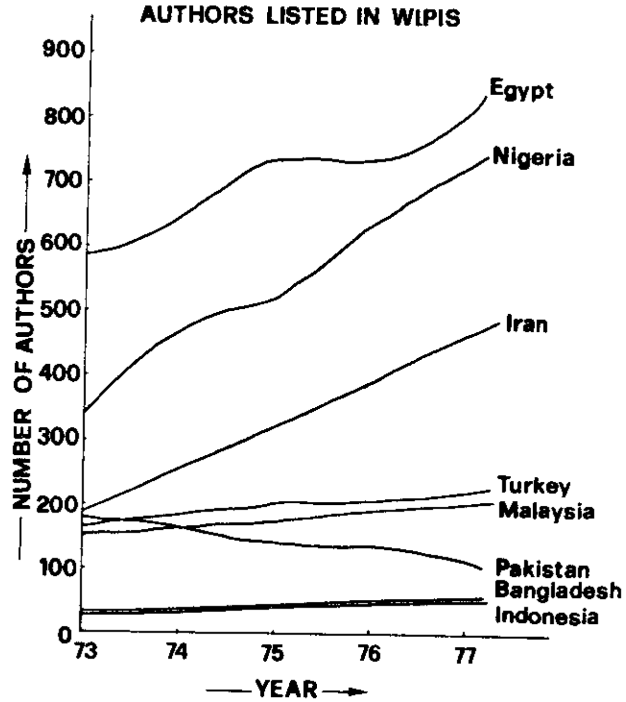
AUTHORS LISTED IN WIPIS
NUMBER OF AUTHORS
YEAR
0
100
200
300
400
500
600
700
800
900
73
74
75
76
77
Egypt
Nigeria
Iran
Turkey
Malaysia
Pakistan
Bangladesh
Indonesia

Fig.8

DEVELOPMENT IN SOUTH KOREA

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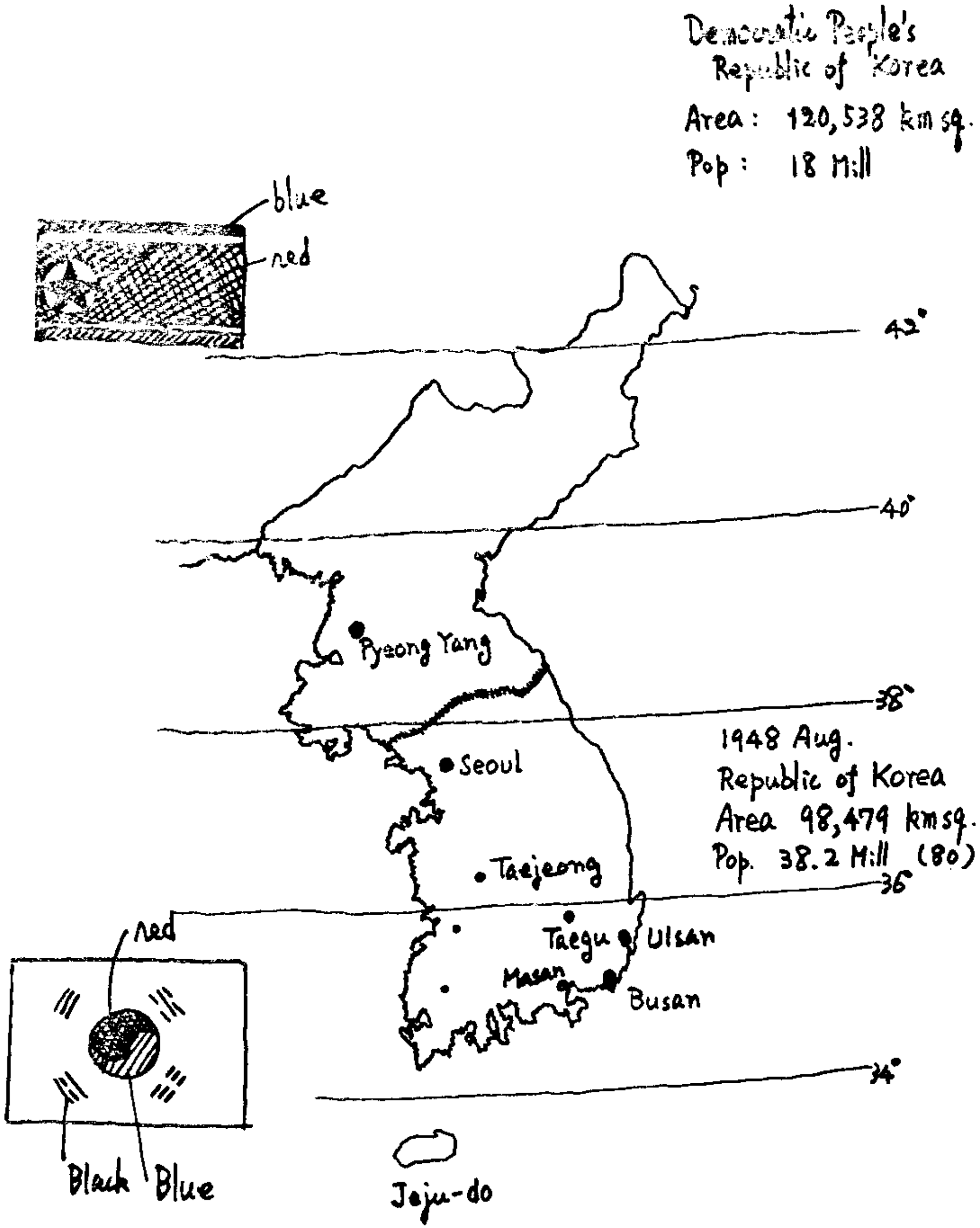

Recent History

1945		Divided
May	1948	UN-supervised elections for National Assembly
Aug.	1948	Republic of Korea (S. Rhee)
June	1950 – 1953	Korean war.
April	1960	Rhee was forced to resign.
June	1960	Election (B. Yun)
May	1961	Military coup (Gen. C. H. Park)
Dec	1963	President C. H. Park
Oct.	1979	Park was assassinated by Kim Chae-Kyu Kyu-Hah Choi (Prime Minister)
March	1981	Doo-Hwan Chun

Fourth Five-Year Economic Plan, 1977-81
(billion won at constant 1975 prices)

1$ ≈ 460 won.

	1975		1977		1981		
	Amount	%	Amount	%	Amount	%	Av. Ann. Growth % 77-81
GNP	9,080.3 ($19.7)	100.0	11,486.6 ($24.0)	100.0	16,214.3 ($35.2)	100.0	9.2
Agriculture forestry, fishing	2,302.8	25.4	2,562.6	22.3	2,997.8	18.5	4.0
Mining & manufacturing	2,697.1	29.7	4,005.5	34.9	6,631.0	40.9	14.2
Social & other services	4,080.4	44.9	4,918.5	42.8	6,585.5	40.6	7.6
Consumption	7,444.4	82.0	8,954.5	78.0	11,983.3	73.9	7.8
Gross invest	2,478.4	27.3	3,097.9	27.0	4,219.9	26.0	7.8
Exports	2,847.7	31.4	4,803.7	41.8	8,474.3	52.3	16.8
Imports	3,870.7	42.6	5,369.5	46.7	8,463.2	52.2	13.0

INDUSTRY (SELECTED PRODUCTS)

		1978	1979	1980	1981
Wheat flour	x1000 metric tons	1,184.1	1,242	1,492	1,439
Refined sugar	"	511.0	625	758	691
Polywood	x1000 cubic meters	2,742.2	2,510	1,693	1,671
Rubber tyres	x1000	6,905.2	10,025	12,328	9,102
Sulphuric acid	metric tons	1,461,399	1,644,797	1,683,322	1,294,345
Soda ash	"	176,090	203,792	221,920	202,063
Urea fertilizer	"	1,185,969	1,165,612	972,876	1,070,089
Naphta	million litres	3,296.2	3,570	3,805	3,906
Kerosene	"	1,099.7	1,417	1,401	1,292
Distillate fuel/oil	"	5,476.2	6,050	6,093	6,228
Cement	x1000 metric tons	15,133	16,413	15,631	15,617
Pig iron	"	2,744.1	5,063	5,577	7,928
Crude steel	"	3,138	5,200	5,790	
Radio receivers	x 1000	4,767.7	4,772	4,143	5,126
Television receivers	"	4,826.5	5,867	6,819	7,697
Passenger cars	number	92,331	112,400	57,037	72,132
Lorries & trucks	"	58,326	78,585		
Electric energy	million kWh	31,510	35,600	37,239	40,207

Economically active population (1981 Average)

	Males	Females	Total
Agriculture forestry & fishing	2,707,000 (31.1%)	2,098,000 (39.1%)	4,806,000 (34.2%)
Mining & quarrying	115,000 (1.32)	9,000 (0.17)	124,000 (0.88)
Manufacturing	1,750,000 (20.1)	1,121,000 (20.9)	2,871,000 (20.4)
construction	806,000 (9.3)	69,000 (1.29)	875,000 (6.2)
Services	3,307,000 (38.0)	2,064,000 (38.5)	5,372,000 (38.2)
Total employ	8,687,000	5,361,000	14,048,000
unemployed	526,000 (5.7)	135,000 (2.5)	661,000 (4.5)
Total labour force	9,213,000 (62.6)	5,496,000 (37.4)	14,710,000

§ Labor Force

	% of pop. of working age (15-64 years)		% of labor force in						Av. ann. growth of labor force (%)		
			Agric.		Industry		Services				
	1960	1980	1960	80	60	80	60	80	60-70	70-80	80-2000
KOREA	54	62	66	34	9	29	25	37	3.0	2.8	2.0
Brazil	54	57	52	30	15	24	33	46	2.5	3.9	2.5
Mexico	51	51	55	36	20	26	25	38	2.8	3.3	3.5
Argentina	64	63	20	13	36	28	44	59	1.3	1.2	1.2
JAPAN	64	68	33	12	30	39	37	49	1.9	1.3	0.7

GNP per capita

	Population (million) mid 1980	Area x1000 km sq	Dollars 1980	Av. Ann growth % 1960-80	Av. Ann. infl (%) 1960-70	70-80	Life 1980
KOREA	38.2	98	1,520	7.0	17.4	19.8	65
Brazil	118.7	8,512	2,050	5.1	46.1	36.7	63
Mexico	69.8	1,973	2,090	2.6	3.6	19.3	65
Argentina	27.7	2,767	2,390	2.2	21.7	130.8	70
Hong Kong	5.1	1	4,240	6.8	2.4	8.2	74
JAPAN	116.8	373	9,890	7.1	4.9	7.5	76

	Birth	death	pop. increase
1970-75	2.88%	0.88%	2%
1975-80	2.53%	0.81%	1.72%

§ Urbanization

	Urban popul. % of total pop.		% of urban pop. Av. Ann. growth %		In large city		In cities of over 500,000		no. of cities over 500,000	
	1960	1980	60-70	70-80	60	80	60	80	60	80
Korea	28	55	6.4	4.7	35	41	61	77	3	7
Brazil	46	68	4.8	4.1	14	16	35	52	6	14
Mexico	51	67	4.8	4.3	28	32	36	48	3	7
Argent	74	82	2.0	2.1	46	45	54	60	3	5
Japan	62	78	2.4	2.1	18	22	35	42	5	9

§ Income distribution

	Year	Lowest 20%	Second quintile	3rd quintile	4th quintile	Highest 20%	Highest 10%
KOREA	72	5.7	11.2	15.4	22.4	45.3	27.5
BRAZIL	72	2.0	5.0	9.4	17.0	66.6	50.6
Mexico	77	2.9	7.0	12.0	20.4	57.7	40.6
Argent.	70	4.4	9.7	14.1	21.5	50.3	35.2
JAPAN	69	7.6	13.1	16.8	21.2	41.3	27.2
INDIA	75-76	7.0	9.2	13.9	20.5	49.4	33.6

§ Average annual growth rate (%)

	Agriculture		Industry		Manufacturing		Service	
	60-70	70-80	60-70	70-80	60-70	70-80	60-70	70-80
Korea	4.4	3.2	17.2	15.4	17.6	16.6	8.9	8.5
Brazil		4.9		9.3		10.3		8.4
Mexico	3.8	2.3	9.1	6.6	9.0	5.9	6.9	4.9
Argent.	2.2	2.6	5.9	1.8	5.7	1.0	3.4	2.6
Japan	4.0	1.1	10.9	5.5	11.0	6.4	11.7	5.5

§ Commercial Energy

Average annual growth rate (%)

	Energy product		Energy consumption		Energy consumption per capita (kg. of coal equivalent)		Energy import as a % of merchandise exports	
	60-74	74-79	60-74	74-79	60	79	60	79
Korea	6.3	4.6	13.9	12.0	208	1,473	70	25
Brazil	8.3	7.3	8.2	7.6	375	1,018	21	48
Mexico	5.8	15.7	7.7	7.8	713	1,535	3	3
Argent.	6.5	3.7	5.5	3.2	1,057	1,965	14	14
Japan	−1.4	3.6	9.8	3.1	1,246	4,048	18	44

Electricity production
1975 ≃4,200 MW
1980 ≃8,344 MW

1980 hydro-electric resourses 1,800 MW (≃22 %)
Nuclear power station 590 MW (7 %)
Oil-fired stations 5,900 MW (70 %)

Plan

By 1991 11,000 MW Nuclear power station
4,000 MW Coal-fired station

"World Directory of Energy Information"
Cambridge Information and Research Services Limited
Gower Pub. Co. Ltd. 1982.

	Merchandise trade (Million of dollars)		Average annual growth rate (%)			
	Exports	Imports	Exports		Imports	
	1980	1980	60-70	70-80	60-70	70-80
KOREA	17,548	22,292	34.1	23.0	20.5	11.8
Brazil	20,131	25,000	5.1	7.5	4.9	4.2
Mexico	15,308	19,517	2.8	13.4	6.4	7.0
Argent.	8,020	10,555	3.4	9.3	0.3	2.1
Japan	129,248	140,520?	17.2	8.9	13.7	4.4

§ % share of merchandise exports

	Fuels minerals metals		Other primary commodities		Textiles Clothing		Machinery Transport equipment		Other manufactures	
	60	79	60	79	60	79	60	79	60	79
Korea	30	1	56	10	8	31		20	6	38
Brazil	8	11	89	50	0	5		16	3	18
Mexico	24	39	64	22	4	3	1	19	7	17
Argent	1	2	95	74	0	3		6	4	15
Japan	11	2	10	2	28	4	23	54	28	38

§ % share of merchandise imports

	Food		Fuels		other primary commodities		Machinery & Transport equip.		other manufact.	
	60	79	60	79	60	79	60	79	60	79
Korea	10	9	7	19	25	17	12	30	46	25
Brazil	14	12	19	37	13	7	36	21	18	23
Mexico	4	8	2	2	10	7	52	50	32	33
Argent.	3	7	13	17	11	9	44	33	29	34
Japan	17	15	17	41	49	21	9	7	8	16

§ Balance of Payments and debt service ratios

	Current account Balance (Million $)		Interest payments on external public debt (Million $)		Debt service as % of GNP		Debt service as % of Exports of goods & Services	
	70	80	70	80	70	80	70	80
Korea	-623	-5,326	70	1,310	3.1	4.9	19.4	12.2
Brazil	-837	-12,871	133	4,142	0.9	3.4	12.5	34.0
Mexico	-1,060	-7,466	216	3,844	2.1	4.9	24.1	31.9
Argent	-158	-4,700	121	827	1.9	1.4	21.5	16.6
Japan	1,980	10,737						

§ External public debt

	Million $		As % of GNP	
	1970	1980	1970	1980
Korea	1,797	16,274	20.9	28.8
Brazil	3,232	37,824	7.2	16.4
Mexico	3,206	33,490	9.7	20.6
Argent	1,878	10,285	7.6	7.2

§ Defense & social expenditure

	Defense expenditure as % of				GNP/capita $	Central government expenditure per capita (1975 dollars)					
	GNP		Central Government expenditure			Defense		Education		Health	
	1972	79	72	79	1980	72	79	72	79	72	79
Korea	4.9	5.5	25.8	30.6	1,520	22	44	14	24	1	2
Brazil	1.4	0.8	8.3	4.3	2,050	13	11	11	15	10	21
Mexico	0.6	0.5	4.9	2.9	2,090	8	8	27	50	8	10
Argent.	1.0	2.5	9.0	14.0	2,390	18	37	19	22	7	5

Ref. Government Finance Statistics Year Book and IMF data files.

Education system (1981) in S. KOREA

	ages	schools	Teachers	Students
Kindergarten	5-6 (1)	2,958	3,961	153,823 (39)
Elementary school	6-11 (6)	6,517	122,727	5,586,494 (46)
junior high school	12-14 (3)	2,174	57,838	2,573,945 (45)
Senior high sch.	15-17 (3)	1,402	55,347	1,823,039 (33)
junior vocational college	18-20 (2)	132	5,941	188,700 (32)
Junior teacher's coll.	18-20 (2)	11	482	10,324 (21)
University	18-21 (4)	89	17,481	535,876 (31)
grad. sch. M.S.	(2)			
grad. sch. Ph.D	(3)			

89 Univ. — State Inst. 15
Private Inst. 74

Duty:

SNU	6 h/w ~ 9 h/w	Phys. Dep.	28 Faculties
Yonsei	9 h/w ~ 13 h/w		12 Faculties
KAIS	3 h/w		6 "

Students in Phys. Dep.

SNU	und. grad ~100×4	grad. 200	600/25 ≃ 24
Yonsei	~60×4	100	340/9 ≃ 38
KAIS		15×5	75/6 ≃ 13

Physical Society 1900
Univ. ~1000
active ~300

Five Year Development Plan

1) 1962–1967 8.3% annual economic growth rate

2) 1967–1971 11.4%

3) 1972–1974 8.6%

4) 1977–1981 9 %

5) 1982–1986

1. emphasis on consumer goods

2.3.4 heavy industries & chemical industries.

3. Continuing nationwide programme of construction, electricity generation, boost agricultural product, building of highways. rapid transit systems, improvement of port facilities

Nation's fisheries : modernization by means of Government assistance and foreign loans

Offshore petroleum
hydro-electric power generation & nuclear power station

Three automotive manufacturing plants along with a growing machine tool industry

long-scale shipyards
heavy industries
chemical industries
integrated iron & steel industry
Textiles, drugs, radio, TV, bicycles, sewing machines
leather products, plywood, handcrafts etc.

§2. Organization of Science and Technology

I) Ministry of Science and Technology

policy, organization, co-ordination, budgeting of Science & Tech.
international scientific & technical organizations
(US. Germany, Japan, India, Taiwan)

Operational units :

a) Atomic Energy Bureau
b) Central Meteorological office
c) National Computer Center
d) Office of planning & management
e) Office of policy & planning
   i) general planning directorate
   ii) Information management directorate
   iii) Manpower planning directorate
   iv) Resources development directorate
   v) Technology development directorate
f) Programme Development & promotion bureau
   encouraging the development of research
   foreign development in science & Tech. → application in korea
g) Technical co-operation Bureau
   works with foreign agencies

Advisory commities:

a) Atomic energy commission
   - peaceful application of nuclear power

b) Committee for the development of science & technology
   directs long-term planning in science & technology.

c) Committee of the establishment of national astronomical observatory

d) Co-ordinating committee for the development of electronic data processing system.

e) Science & technology fund operation committee

II) KOREA DEVELOPMENT INSTITUTE (KDI) 1971-
to help the Government in formulating policies for national development. It is an independent organization and carries out investigations on relevant projects

III) KOSEF - Korea Science & Engineering Foundation
Grants are given for research & development projects

ex. 1983
$ 60 Millions for R&D in science & engineering
$ 800,000 (1.33%) for pure science

Ministry of Education → research grants ≈ $ 20 Millions
Other privates research grants ≈ $ 1 Million
(tax exemptions)

R&D : ≈0.2% of GNP

§3 Institutes

I) Seoul Science Park

a) KIST (Korea Institute of Science & Technology)
It was established in 1966 as a joint project of Korean & US Governments. An integrated applied research institute for support of Korea's industrial development programmes.

i) functions: solution of technical problems involved in new production processes, development and quality improvement of new materials & products. also to transfer scientific and technological developments from universities & research institute laboratories to industry.
10 specialized lab: chemical engineering, organic chemistry, food & biological engineering, industrial economy, electronic data retrieval, mechanical engineering, metallurgy materials research, electronic engineering, laser research
2 technical centers: precision machine technology & foundry technology
3 research centers: shipbuilding research, maritime development, ocean research.

ii) Research on a contract basis for the Government, industry and foreign countries.

iii) ~ 1000 staff members

iv) KIST maintains an extensive network of relations with other Korean and foreign research institutes.

b) KAIS - Korea Advanced Institute of Science

Established in 1973 to educate scientists & engineers for Korean industry, to encourage the growth of science & technology, to carry out research on topics of relevance to the country's industry

1973 106 students
1979 250 "
1983 ≈ 400 students, 45 full-time staffs + α part-time

Degree courses: basic science, biological science, chemical science, electrical science industrial sciences, material science. mechanical science

Research projects: Computer system, telecommunications. solid state physics, applied biochemistry fermentation & enzyme technology, microbiology, food science & technology, applied mathematics, engineering design, biochemical engineering, pharmaceutical science & technology, physical and chemical metallurgy, chemical kinetics and polymer technology.

c) KORSTIC - Korea Scientific & Technological Information Center

d) KDI (Korea Development Institute)

e) ADD - Agency for Defence Development

Defence science and technology research materials and equipment development

II) Science Town

Dae Duk ...... 120 km south of Seoul

It started at 1974.

A number of industrial research institutes.

a) National Industrial Standards Research Institute

It carries out standards testing on industrial products. It is also involved in research and development on testing methods. Technical advice and training services are provided for industry. ~60 staffs.

b) National Institute of standards.

Research and development on modern and precise measurement methods. Technical advice for industry. ~100 staffs.

c) Mechanical Engineering Research Institute 1977-

Aid in development of the country's machinary industry.

d) National Inspection for Agriculture and Materials

e) Petrochemical Research Institute

etc.

III) National Institute of Electronics ?

mainly design computers.

IV) Korea Atomic Energy Research Institute 1973

Research and development on peaceful uses of atomic power.

12 physical science labs.; cancer hospital

- Basic research: laser optics, neutron physics, radio-chemistry, molecular biology, radiation biology, plant genetics & mutations, plant nutrition, agricultural chemistry,
- Applied research: nuclear fuels, industrial applications for radioactive materials.

lack of natural resources:

To survive: development of sophisticated technology supported by basic sciences.

Government plan & emphasis:

- SLIC Super large integrated circuit
- Laser telecommunication system
- computer
- biotechnology

Manpower: 60 % students science & engineering
40 % " social science

Spirit of modernization and development
Strong collaboration of research institutes and industries
Strong collaboration of Government and industries
Manpower in good (high) quality
Stability of Government.

"New Community movement" 1972–

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SCIENCE AND TECHNOLOGY IN DEVELOPMENT - A PRELIMINARY STUDY OF THE MALAYSIAN CASE

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Introduction

The economy of Malaysia (then Malaya) during the Colonial period was based primarily on the export of rubber and tin. In the years before independence in 1957, gross export proceeds accounted for 45% of the Gross Domestic Product (GDP). Proceeds from the export of rubber and tin contributed about 85% of the total value of exports. In the 1960's the annual rate of growth of the country's GDP was about 6%. This further accelerated to 7.8% during the 1970s. Per capita consumption had also increased from M$856 in 1970 to M$1,445 in 1980, whilst the rate of saving to GNP has increased from 21% during 1971-75 period to 29% during 1976-80. The share of gross investment in GNP has increased over the same period to 26%. Based on these macro indications we can say that the country has moved into the semi-developed category.

To a large extent the sustained growth of GNP in Malaysia has been the result of the country's wealth in natural resources. Large reserves of land, timber, tin and petroleum has given a boost to the country's economic growth. At the same time World Bank-backed government policies to improve the yield of rubber trees, diversification of the economy to include production of oil palm, import-substitution and export-oriented industrialization had all added to up export value from M$3.2 billion in 1961 to M$5.1 billion in 1970 to [illegible] billion in 1980. The result of the policy of diversification can be seen in Table 1 where the contribution of rubber export had declined from 48% in 1961 to 17% in 1980 and that of manufactured exports had increased from 5% to 20.5% over the same period. Due to these developments over the years the unemployment rate had

declined from 7.8% in 1970 to 5.3% in 1980. We have therefore moved from a labour surplus economy to one relative scarcity in labour especially in plantations and agriculture (sector of lowest returns to labour) and the high growth construction sector which are now using cheaper immigrant labour from Indonesia, Philippines and Thailand (1).

Agricultural development

In 1980 agriculture still formed the largest item in terms of contribution to the GDP (22%), but it is expected not to be by 1985. In fact the share of agricultural exports had declined from 52% in 1970 to 36% in 1980 as a result of the emergence of crude oil and manufactured goods as important export commodities. Nonetheless, agriculture still provides 41% of total employment in 1980 compared to 51% in 1970.

Although the incidence of poverty is highest in the agricultural sector (in 1975, 69% of agricultural households are living below the poverty line) budget allocations for this sector have declined from 27.3% in 1970 to 13% in 1981. Over the years agricultural expenditure was allocated mainly for three strategic programmes - replanting of rubber trees (highest allocation was 67% during the First Malaya Plan 1956-1960); drainage and irrigation (highest allocation was 36% during the First Malaysia Plan 1966-1970); and land resettlement (highest allocation of 51% for the Second Malaysia Plan period 1971-1975).

Rubber replanting and irrigation schemes are aimed at improving the productivity of existing settlements. Due to difficulties of extending existing cultivated areas and the fact that rural landlords formed the backbone of support for the Malaya component of the ruling party, land reform was never considered as an alternative for alleviating rural poverty. Instead the state has spent millions clearing virgin jungles to set up land schemes planting rubber and oil palm managed and supervised by government employees. Though about one-half of agricultural allocations were reserved for land development, this benefitted less than 5% of the rural population.

Due to historical reasons, the marketing of Malaysian rubber is today dominated by transnational companies. Thus rubber prices are not dictated in producers countries but in the developed countries such as the US and the UK. Falling prices had led to a decline in planted rubber acreage in Malaysia - from 1,718,100 hectares in 1971 to 1,697,300 hectares in 1980, sustained mainly by government land schemes. Nonetheless, great advances in the development of high yield clones have made possible an increase in production - from 1,270,400 tons

in 1971 to 1,463,900 tons in 1980.

Due to the extension of irrigation facilities to cover 83% of rice lands (641,530 out of 771,080 hectares) Malaysia was able to produce 82% of its rice requirements in 1981. However, only 224,250 hectares of land was double cropped, mainly with imported technology. It was estimated that in 1982, Malaysia imported about 68% of her fertiliser requirements. 30% or so of the poor households in Malaysia's premier irrigation scheme, the Muda Irrigation Scheme, are perpetually in debt, not for consumption credit (as before) but production credit which has mounted over the years from M$47 in 1966 to M$2,772 per family in 1978/79. A World Bank Report shows that some 70 cents of every dollar generated by the poor farmers in the scheme was siphoned out of the region (2). Within the scheme increases in income were much higher for the larger holdings (M$211) than for the smaller ones (M$116) least for the landless labourers (M$93). We therefore find that in a capital intensive scheme such as that of the Muda where more than half of the padi farms continue to be below the poverty line farm size of 0.228 hectares per capita, between 30-40% of the farming population still remain below the poverty line. This shows that it is not further technological inputs but land redistribution that will go a long way in reducing the number living below the poverty line.

Industrial development

Before independence in 1957, there was hardly any industries to speak of in Malaya. Value added in manufacturing contributed less than 5% to the GDP, confined to elementary processing of local raw materials and based on family farms and cottage industries. Moreover, because Malaysia was a captive market under the Commonwealth Preferential System, there was no incentive for foreign manufacturers to locate their industries here to defend their market share. Most important of all, at that time, the overall rate of returns to investment was relatively higher in the advanced industrial countries. It was only in the second half of the sixties as a result of strong unions and increasing costs of production, saturation of domestic market, foreign competitors operating from within, and economic rationalism of newly emerging countries preventing unlimited flow of exports, that foreign investments started flowing to the developing economies. This world trend coupled with generous tax incentives provided by the government resulted in the dramatic growth in manufacturing's contribution to the GDP from 8.7% in 1961 to 13.4% in 1970 to 20.5% in 1980. For the first time in 1980 the manufacturing and construction sectors contributed a larger proportion to the GDP than the agricultural sector.

Industrial development has evolved from primary processing in the 1950's to import substitution in the 1960's, and labour intensive export oriented industries such as electronics and textile manufacturing in the 1970's. The eighties are likely to witness the expansion of resource-capital-intensive and energy based heavy industries as well as industries employing high technology - a result of plentiful local resources (gas, petroleum, rubber, oil palm and tin) and also because of the maturation of the manufacturing sector.

Efforts to increase industrial development centred mainly on the provision of infrastructures and liberal investment incentives in the form of tax exemptions and tariff protection. During the early phases of industrial development, plantation owners' fears of increase in cost of living for their workers coupled with anxiety of traders profits had mitigated against the use of tariff protection to nurture infant industries. Instead reliance was placed solely on fiscal incentives (tax holidays) and infrastructural development (which took up about50% of public sector investment). Progressive worsening terms of trade and high unemployment had led to a drastic change in industrial policies. Tariff protection of between 15-50% was instituted and the Pioneer Industries Ordinance was replaced by the Investment Incentive Act (1968) which provides total or partial relief from the payment of income tax (@ 40%) and development tax (@ 5%) to investors for a period of between 2 to 10 years depending on capital expenditure (Investment Tax Credit); number of full time paid employees (Labour Utilization Relief of 2-8 years); proportion of product exported; location of enterprise (Location Incentive providing tax relief of 5-10 years to encourage rural location to stem the flow of rural-urban migration); type of product, degree of modernisation of plant and use of local resource eg. rubber. By 1983, 94 industrial estates covering a total of 10,736.5 hectares were developed providing cheap factory sites, transport communication and general infrastructural facilities with the aim of promoting labour intensive and geographically dispersed industrialiaation. The Free Trade Zone Act 1970 provided for the establishment of export processing zones with special facilities for duty-free entry of materials and goods and minimal custom procedures for export of processed and manufactured goods. By 1982, there were ten Free Trade Zones. Notwithstanding the provision of these generous incentives the Industrial Co-ordination Act was implemented in 1976 to place existing or proposed manufacturing enterprises (with shareholders' funds of less than M$250,000 and those employing less than 25 full-time employees) under bureaucratic control with regard to their nature, size and management. But because Malaysia is a highly trade dependent economy: the ratio of exports to GDP was 50.3% in 1961 and 52.2% in 1976 the country can never have a complete free hand in licensing, controlling and protecting domestic interests.

During the ten year span of 1970-80, about 416,000 new jobs were created within the manufacturing sector, a substantial part of which is attributable to the growth of manufactured exports. By the end of 1978, total employment generated within the Free Trade Zones (FTZ) was 80,920, representing 11% of the employment in the manufacturing sector. In one Free Trade Zone alone (whose labour force comprises 70% of all Free Trade Zone workers) more than 70% of the workers are females. In 1974, electronic assembly plants which produced circuit fittings, office machine parts, television and radio parts, polished silicon wafers etc. accounted for over 90% of the exports from the FTZs of Malaysia. Their essential raw materials are imported from other production units of the parent company located elsewhere in the world, their only significant local input being electricity, apart from labour. (In one company studied 60% of material inputs were imported whilst the other 40% comprised primarily of electricity and other insignificant items.)[3]

An incomplete census of various FTZs in 1978 revealed that about 71% of enterprises located in them are foreign owned, 23% are owned by and managed by foreign companies on a majority basis, only about 6% are Malaysian owned. "High technology" industries such as the electronic multinationals are presently exempted from the policy of Malaysianisation of at least 70% of corporate equity by 1990 even though their main work involves primary assembly line operations which can be easily carried out by young school leavers or even primary school drop-outs. About three-quarters of the FTZ enterprises had reported that such operations were fully manual whilst 24% were using semi-mechanised techniques.

As a majority of FTZ companies are foreign owned, a majority of them (about two-thirds of them) need not have any agreement or outside consultancy or management contracts. Of those who have some explicit agreements, these are with their parent companies. Good commodity prices coupled with the discovery of petroleum has enabled the Malaysian government to press ahead with the Malaysianisation of corporate equity. But, in the absence of any significant local research and developmant (R&D) activities, technical agreements and joint ventures are about the only means whereby local capitalists (including the government) can be involved in any form of industrialisation. It is therefore important to look into the implications of these various forms of joint-ventures and agreements.

Transfer of technology in Malaysia

During the late 50s and the early 60s, it was widely held that backward countries need not undergo the same arduous and costly process through which the advanced countries had passed in order to achieve their present state of technological and economic development. Through the transfer of technology, developing countries could cheaply acquire the technological skills and knowledge already possessed by the industrialised countried. As the subsequent analysis of the Malaysian case will show, such an attitude is both naive, simplistic, and overly optimistic.

Over the years, in response to the changing conditions and pressure from developing countries developed countries have changed their forms of domination over them. From control over the extraction of raw materials and supplying of manufactured goods, developed countries have now gained a sufficient share of the industrial production facilities through direct investment and monopolisation of technical know-how required in manufacturing. In the case of Malaysia, even though foreign subsidiaries operating in the country have accepted the policy of equity dilution technological and management control continues to residee in foreign hands via joint ventures and technology license agreements with their respective parent companies. Thus, the real extent of foreign control in the Malaysian economy is still pervasive and far more extensive than indicated by the proportion of equity ownership.

Up to 1980, of the 635 agreements screened by the TTU (Malaysian Transfer of Technology Unit), 57% were technical know-how agreements; 16% were management agreements; 11% were joint-ventures; 10% were service agreements: 5% were trade-mark agreements and 1% were for basic engineering [4]. Most transnationals (TNCs) operating in Malaysia prefer to adopt the method of "direct transfer of technology" where turnkey agreements provide the whole package deal from plant construction to the production stage. In almost all cases, these companies have full control of the operations in the plant by providing all the technical and managerial resources. Examples include the electronics, electrical and pharmaceutical industries. The justification given by the TNCs for preferring such agreements is the necessity to maintain the technical quality and efficiency of their production.

Transfer of technology via license agreements is costly. First, there is the direct and visible cost which includes monetary remittances for machinery, equipment, personnel, technical information and the like. There is also hidden or indirect costs which result from restrictive provisions (included in agreements)

such as the compulsory purchase of raw materials, goods and services, export restrictions, R&D restrictions and inappropriateness of technology imported. Data available for only 211 agreements (out of the 635 registered) signed between 1970-80 shows that total payments amounted to about US$ 1518 million.

Up till now, transfer of technology has been limited primarily to the physical transfer of tangible material forms such as equipment, machinery and plants. However, a more important and critical aspect of this process has been ignored i.e. the diffusion of technical know-how and skills. In fact, many TNCs attempt in various ways to prevent such a diffusion of know-how in order to perpetuate their hold in most countries. In Malaysia, a large number of agreements impose restrictions regarding the transmission and diffusion of technology purchased. For instance, some licenses stipulate that licensees should not allow the machinery to be seen by the public. Other agreements require the licenses to "cease all or any use of technical know-how and drawings for any purpose on termination of the agreement".

Similar restrictions are placed on R&D with particular regard to adaptive research. There rarely exists a provision in agreements for adaptation of equipment of product by the licensor to suit local conditions. On the contrary, some licensors even specify that no adaptations could be made to the licensed product or equipment. There are even cases where licensees are required to "disclose to the licensor all inventions, processes and information which may be developed relating to the licensed product and hereby grants to the licensor and its subsidiaries the free and unrestricted right to file application for letter of patents on improvements or new discoveries made by the licensees. In contrast, licensees in general have to pay additional fees to obtain any new technical know-how, discovery or developments during the term of the agreement.

As a result of all these restrictions, Malaysia has experienced very little transfer of skills from TNCs. This is particularly true of turnkey projects or other package deals where local technicians have no opportunity at all for "learning by doing". Neither have they any opportunities for building skills through the experience of selecting, installing or constructing plants. The failure to acquire technical know-how through existing process of technology transfer not only seriously limits technical change after the initial investment, it also limits the capability to integrate results of national R&D into production systems. And since local companies are in no position to negotiate for individual components of the package concerning investment, technology marketing and management and import only what they need, the country probably ends up paying more for the

imported technology than is necessary. The situation in Malaysia is by no means unusual. Studies carried out in other developing countries show similarly unfavourable terms in the transfer of technology [5].

Today, Malaysian contracts constitute the largest proportion of all international construction contracts won by Japanese enterprises. Malaysian government's insistence that local companies be included in joint-ventures in the implementation of such contracts have only resulted in the setting up of front companies. For instance, the front company with only a paid-up capital of US$ 1 was set up to build the premier urban renewal project Daya Bumi at a cost of approximately US$ 150 million. Clauses to include training of locals can end up as mere tours of factories and scenic spots in Japan. Industrial unrest such as strikes, high turnover and downing of tools is common at such construction sites as locals feel unfavourably discriminated against under foreign superiors and skilled workers.

The Malaysian Finance Minister once said that "Foreign companies are still bogies..... they have not transferred their technology to our people, they are relying on domestic funds and borrowing from banks here, and they have not trained our people. They are still the same....." [6]. Yet, the government has only recently decided to purchase a completely new plant to produce the made-in-Malaysia car, some parts of which will be produced by robots. The rationale given was that since the step-by-step progression in technological advancement achieved by some local industries (for instance, from the export of timber logs to plywood and the assembly of completely knocked-down-furniture) had taken an inordinately long time, Malaysia will have to try to achieve technological sophistication by going for heavy industries (such as steel production, aluminium smelting) without having to pass through the intermediate stages of technological development. The made-in-Malaysia car project is supposed to form the basis of industrialisation based on high technology. This joint-venture with Mitsubishi is based on 70:30 equity ratio favouring Malaysia, With the help of tariff walls and for a mere US$ 54 million initial capital Mitsubishi will capture 60% of the domestic market where it now holds scarcely 8%.

If it is true that developing countries such as Malaysia cannot hope to develop their industries without importing foreign technology, it is equally true that unless a concurrent programme for the development of local technical capability for R&D is implemented systematically, developing countries will remain perpetually dependent on foreign suppliers for technical know-how. One way of achieving technical capability for R&D is to carry out adaptive research. This helps not

only in the absorption of foreign technology but also assists in the development of alternative technologies that are more appropriate to the Malaysian context. As the development of local R&D component is crucial to the process of technology transfer, our next section will examine this aspect in greater detail.

Research and development (R&D)

Most TNCs in Malaysia are engaged in simple assembling of imported components rather than actual manufacturing as shown in the case of the electronics sector. In one case of a French car company assembling completely-knocked-down parts, 90% of the components were imported. In fact, TNCs seldom link up with local ancillory establishments for supply of raw materials using the excuse that local suppliers were unable to meet the required technical specifications. Even though the government has stipulated that local content should be increased over the years for car assemblers, this has not been strictly enforced up till now, due to a very strong car lobby.

For reasons of economies of scale, most TNCs depend on their parent companies for R&D work. Of the few TNCs which have active R&D programmes such as those of Harrisons and Crosfields Research and Advisory Services, Dunlop Research Centre and ICI (Malaysia) Ltd. Company - these deal mainly in agro-based research.

The bulk of R&D activities in Malaysia is carried out by government agencies. These include MARDI (Malaysian Agricultural Research and Development Institute), RRIM (Rubber Research Institute of Malaysia), IMR (Institute of Medical Research), SIRIM (Standards and Industrial Research Institute Malaysia), Tun Ismail Atomic Research Centre and institutions of higher learning. See Appendix I for more details. As we are still basically an agricultural country, agricultural research constitutes the largest item in total R&D allocations, taking up about US$ 41 between 1981-85. The exact figure for total R&D expenditures is not available (partly due to difficulties of defining what precisely constitutes R&D and in part due to a lack of systematic compilation of data thus indicating lack of importance attached to local R&D). A rough estimate could be about 0.5% of the Malaysia GNP. A comparison of this can be made by looking at Table 2 which provides R&D figures for some selected countries.

To give a rough idea of how R&D activities are programmed in Malaysia, we present below some details on R&D activities with regards to rubber, our most important export until the discovery of petroleum. Today, the world industry is worth some US$ 100 billion embracing some 100,000 products of which 30,000 are

natural rubber based. The bulk of rubber manufacturing industry is situated in the US, Japan and other industrialised countries. Rubber based products in Malaysia constitute only a mere 1.6% of total manufacturing export valued at US$ 2,295 million in 1981.

Based on the number of applications for patents, we can conclude that there has been only a negligible number of innovative or new rubber product made in Malaysia. Between 1950-1978, only two patents relating to rubber products were registered locally. This is not surprising at all as only about 20% of Malaysian rubber product manufacturers carry out any form of R&D activities and these are usually the larger TNCs ot joint-venture companies. Most of these either have license agreements with their foreign partners or were able to obtain technical aid from their parent companies. Examples are Dunlop Malaysia Industries Ltd., and Goodyear Malaysia Ltd. Only one large locally owned company carries out R&D work on tyre manufacturing. This is done with the help of a technical consultant from Taiwan. Private industries' annual expenditure on R&D come up to approximately US$ 2 million. This amount to only about half of one percent of the total sale value of rubber products. To be effective, R&D should comprise at least two per cent of the annual turnover of a particular product.

R&D work in rubber is also primarily carried out by government institutions. The Malaysian Rubber Research and Development Board (MRRDB) was set up to determine policies and programmes for rubber research, development and promotion. It has two operating units responsible for R&D work: the RRIM located in Kuala Lumpur and the Malaysian Rubber Producers Research Association (MRPRA) in London. The MRRDB derives its funds from the levy of research cess of US 1 cent per kilogram of rubber exported. This gives an annual revenue of approximately US$ 17 million.

RRIM concentrates its R&D work on latex technology, engineering application of rubber, tyre development and testing. It also runs a technical advisory service to aid rubber product manufacturers. Most of their R&D activities are therefore based on enquiries from manufacturers. For the last quarter of 1982 alone, there were about 112 such enquiries.

MRPRA with its sophisticated research laboratory in London carries out both basic as well as applied research in rubber physics and chemistry, and also work related to the development of new forms of rubber. Now that Malaysians own nearly the whole of the plantation sector, one may question the justification to continue funding and retaining our rubber R&D activities in London.

National science policy: some remarks

Finally, we would like to make some remarks on government attitudes as reflected in its policies towards the development of science and technology in Malaysia.

During the last decade, large amounts of petrodollars had been used to purchase and thus Malaysianise the many companies which were previously held by foreigners (mainly the British). However, the government has only recently turned its attention to the problem of technological dependency. But it is attacking the problem by purchasing wholesale turnkey fashion sophisticated plants to produce steel, cement and cars. It also relies overly on foreign consultants to plan and implement development projects such as ports, irrigation schemes and highways. Instead of developing our own R&D, wholesale reliance on foreign expertise had resulted in unnecessary wastage - of both time and resources. A few examples are given below to illustrate various effects of such unthinking dependency on foreign expertise.

The following case shows what can happen when blueprints designed with the resources of a developed country in mind are used for projects in developing countries. In the mid-sixties, after a foreign construction company had completed its planned obligations in the World Bank financed Muda Irrigation Scheme, the Malaysian government had still to cough out an additional US$ 40 million (to the original US$ 200 million) to link up the tertiary canals. Furthermore, these canals were to be built by local engineers and it took some time for the authorities to realise that the civil engineers trained in Malaysia are less suitable for the task than hydraulic engineers. It was only as late as 1972 that a decision was taken to train engineers in a more appropriate way for agricultural uses.

Another example is provided by the case of the foreign consultant companies appointed to plan and construct the major east coast port at Kuantan. Unfortunately, the blue-print for the port was prepared without due consideration given to local sea and weather conditions - in particular, the effects of the rough seas during the northeast monsoon season. The port thus showed serious structural weaknesses even before it was due to be opened for operations. Major repair works costing as much as the original price tag had to be instituted by another foreign consultant company!

Besides the problem of overdependency on foreign expertise, lack of administrative co-ordination and proper planning also contribute to wastage of limited resources. One typical example is that regarding the choice of site for Tun Ismail Atomic Research Centre. After spending nearly US$ 1/2 million on clearing the chosen site, the authority "discovered" that another government body, the National Electricity Board, had the extension of trasmission lines in the same area. Fearing that these lines may affect the sensitivity of the electronic equipment to be installed in the atomic centre, the original site was abandoned and a new site had to be found. All this wastage in money and time could have been saved a more careful planning and better co-ordination among various government agencies.

Up till only recently, there seems to be very little commitment on the part of the government to develop our own science and technology capability. This is indicated by the fact that we still do not have an explicit national policy for science and technology development. Though the Ministry of Science and Technology has now been given the task of formulating the national science policy, they do not have the clout or mandate and funds to ensure that such policies and guidelines will be effectively implemented. In 1975, the National Council for Scientific Research and Development (NCSRD) was set up with the primary task of monitoring, evaluating and coordinating scientific and research development in support of national development. However, their role is only an advisory one and such advice, no matter how sound and viable, as shown by past experience, has been frequently ignored or rejected.

Therefore, the most important ingredient in the development of indigenous scientific capability is the necessary political commitment to the cause. Lack of this commitment due to shortsightedness can lead to stunted economic growth after the initial spurt of import substitution. This proved to be the case with Malaysia where the recent slowdown in growth was followed by the call for a second round of import substitution and the nascent focus on technology development in the country. Steps have also been taken to increase the number of technicians and scientific personnel. New vocational and technical institutes have been set up to increase the proportion of students from 4.6% of the total enrollment at upper secondary levels in 1980 to 6.3% in 1985. However, this cannot be considered as adequate in view of the very rapid rate of economic expansion experienced over the last decade (see Table 3). In fact, the development of educational facilities in the past have been disproportionately geared towards producing professionals and university graduates. Far less emphasis had been placed on the training of the large number of supporting skilled manpower needed. As a consequence, the country today faces an acute shortage of skilled labour. As a short term measure, the government has tried pushing the responsibility for training such intermediate level personnel onto the private sector which up till now is reluctant to shoulder

such a burden unless it is incorporated as part of an agreement for award of valuable contracts to foreign construction and manufacturing firms. Hence witness the collapse of training schemes fostered by the Ministry of Labour and Manpower on private local contractors.

One crucial and very basic aspect that is absent in the scientific and technological infrastructure in Malaysia is the lack of an information service for the dissimination of scientific and technological knowledge. There is an acute need for such a service especially for agricultural and industrial workers if only to create an atmosphere where scientific and technological development can thrive.

Extension work and information services provided by existing government organisations such as the Department of Agriculture and the Rubber Smallholders Development Authority are inadequate. During the recent outbreak of the "redpost" in the Muda Scheme rice fields, farmers had complained that they seldom received visits from extension workers even though they respected and valued the "educated" and scientific information given by them.

There is, on the other hand, an even greater dearth in terms of elementary scientific and technical educational facilities for industrial workers. During the recent recession, even the very small number of literary adult education classes were closed down as a result of budget cuts - an unjust and short-sighted move.

It was only recently that the mass media - particularly the TV - was utilised to popularise and dissiminate scientific and technical information and knowledge. This is an encouraging move. However, such efforts should be quickly stepped up and other media should be involved to widen the coverage and effectiveness of such programmes. For instance, the state could initiate and sponsor popular science magazines for a start. These should be written at a level easily understood by the average worker with only primary or lower secondary school education. The function of popularising science is crucial to the development of scientific development in any country. However, Malaysian scientists have in the past seldom come forward to contribute to this effort. Perhaps, with government commitment and support, these scientists will be persuaded towards this effort.

Conclusions

In this paper, we discussed some of the problems relating to the development of science and technology in Malaysia. We believe Malaysia is capable and has the potential of advancing itself in this field if she can overcome systematically some of the problems which hinder the country's expansion into this important area of development.

However, even though this paper has not touched sufficiently on the social aspects of science and technology development, we have pointed out that scientific advancement can by no means be equated to the overall upliftment of the living standards of the poorer sections of the population. Science and technology development does not take place in a vacuum. It can only be expressed through certain social and economic structures. If these do not favour the poor, then scientific and technology development in such contexts will not mean much to them. To quote our country report for CASTASIA II "Even with rapid advances in science and technology their beneficial impact on the poorer sections of the population is at best marginal". (7)

Notes and references

1. Data on the economy is culled from The Fourth Malaysia Plan 1981-85 and the Economic Report various years.
2. The World Bank World Development Report 1981,(Washington 1981).
3. ILO-ARTEP Report: The Role of Free Trade Zones in the Creation of Employment and Industrial Growth in Malaysia, 1982.
4. Chee Peng Lim: ILO Report on The Transfer of Technology in Malaysia, 1982.
5. See, for instance, Constantine Vaitsos, Strategic Choices in the Commercialization of Technology: The Point of View of Developing Countries, (Mimeograph 1970).
6. Far Eastern Economic Review, August 22, 1980.
7. CASTASIA II Country Report on Malaysia, 1981.

TABLE 1

Structure of Exports by Commodity Groups, Malaysia (in percentage)

Commodity	Year		
	1961	1970	1980
Rubber	48	33	17
Tin	16	20	9
Sawlogs	4	12	9
Sawn Timber	2	4	4
Palm Oil	2	5	8
Crude Petroleum	3	4	25
Manufactured Goods	5	7	21
Others	20	15	7
Total	100	100	100

TABLE 2

Research and development expenditure as a percentage of GNP for selected countries

Country	Year	Percentage of GNP
Low Income Countries		
Burma	1973	0.10
India	1979	0.60
Sri Lanka	1978	0.17
Pakistan	1974	0.14
Indonesia	1979	0.4
Middle Income Countries		
Thailand	1979	0.26
Philippines	1979	0.17
Mongolia	1980	0.13
Korea, Rep.	1979	0.6
Iran	1972	0.3
Singapore	1978	0.2
High Income Countries		
USSR	1979	4.7
New Zealand	1977	0.4
Japan	1979	2.10
Australia	1977	1.0

Sources: 1. Statistical Yearbook, 1980, Paris, UNESCO, 1981

2. CASTASIA II Country Reports, 1981

TABLE 3

Malaysia: scientific and technological manpower

Year	Population (thousands)	Total Stock. (thousands)	Total Number (in units)	Scientists and Engineers: Breakdown by field of educational training (in units)					Technicians
				Natural Sciences	Engineering and Technology	Agricultural Sciences	Medical Sciences	Social Sciences	Total Stock (thousands)
1973	11,454.7	217.0	217,041	8,214	25,156	1,429	24,945	157,297	50501.1
1980	14,261.2	340.5	340,520	13,980	40,720	2,530	40,390	242,900	935.5
1985	16,179.5	413.1	419,130	18,150	53,570	3,050	49,120	295,240	1227.1
1990	18,143.0	522.8	522,774	23,656	70,989	3,680	66,049	358,400	1582.4

The 1973 population figure was estimated as at December, 1973. Its source is from the "Vital Statistics" - Peninsular Malaysia, Sabah and Sarawak, 1976. The source for 1980, 1985 and 1990 population figures is the Fourth Malaysia Plan,1981-85, p. 218.

PHYSICS AND DEVELOPMENT

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ABSTRACT

This paper discusses development in a broad sense and suggests the need for harnessing both the human and natural resources of Sri Lanka. A way of including this in training programmes is discussed . To do this effectively three areas of research are suggested.

1. INTRODUCTION

I am neither a physicist nor a person directly involved in development planning, yet the relation of science to development has over and over again drawn my attention in my work situation. Therefore I take this request to present this paper as an opportunity to give serious thought to this subject in order to get a more general direction to my work. This takes the form of a historical and philosophical discussion.

Sri Lanka is an island in the Indian Ocean at the southern tip of the Indian subcontinent, covering an area of about 65000 square kilometres. It consists of a central mass of mountains surrounded by broad coastal plains. It has a population around 14.86 million with historical roots going back as far as 2000 BC. Four of the greatest living religions of the world, namely Buddhism, Hinduism, Islam and Christianity have found their rallying point in this land. To contribute to its development we have to understand the meaning of development.
The concept of development is used in different senses. It is therefore best to consider it in as broad a sense as possible so that the position of our country at present, how we got there and why, may be discussed. It is a difficult task to unravel the connection between physics and development.

In this paper it is done through a discussion of science, technology and development. This will lead inevitably to basic questions of the links, if any, between science, technology and development and the strength or weakness and the precise nature of those links. A proper approach to understand these links may be through an initial historical study of changes in developed countries like Britain, Germany, the USA, the USSR and Japan. In order to discuss Physics and Development in relation to Sri lanka it is instructive to study (i) the presence, if any, of the essence of Science and Technology in Sri Lanka before the period of colonization, i.e. before the 15th century (ii) the status of science and technology, economic, social and political structure of the colonizing powers namely the Portugese, the Dutch and the British at the time of colonization and the characteristics of these colonizing powers which had enriched of stifled the growth of Sri Lanka (iii) the way imported technology, mostly in the form of imported machinery without adequate transfer of the associated technical know-how, has diffused into the Sri Lankan society after independence. These three are areas of research. But for this paper, from a cursory view of the international and national scene on science, technology and development the importance of suitable training programmes in general, and in particular, in Physics and Mathematics is discussed.

2. UNDERSTANDING DEVELOPMENT

Development is a process of total change. In man it involves a change of values. A change from negative values such as fatalism, superstition, passivity, fear, elitism and self-centredness to new positive values. For example the change can be from fear to courage, from superstition to rationality, from silent passivity and fatalism to creative initiative. Well thoughtout training programmes within an educational system can bring about this transformation.

For the whole nation the process will be one of movement towards changes in areas of economic, social, political and cultural structures. All this has to be brought about through man. Political and cultural changes will not

be discussed in this paper. But only social and economic development measured in terms of goods and services produced through the application of Science and Technology will be discussed . For the sake of completeness we shall formally define science and technology. Science is the accumulation of basic systematic knowledge of the universe with its natural resources; and technology is the application of such knowledge to the construction of a pool of ideas useful in the production of goods and services which are assumed to contribute towards social and economic development.

So we shall focus our attention on two broad areas of development, namely (i) development of man through a change of value systems and (ii) social and economic development brought about through production of goods and services from the application of science and technology. Broadly this involves the development of the human and natural resources of the country.

Science has gone a long way in trying to understand the natural resources but the development of man is yet to be given the pride it deserves. A development programme with emphasis only on the development of natural resources cannot make a happy and contended nation. For, a nation with material wealth but with only avarice and self-centred people can never be harmonious. Therefore we look forward to an integrated development of human and natural resources. Yet ultimately, since it is through man that changes have to be brought about, the major emphasis should be on Human Development. The transformed man with a new system of values will have (a) self esteem, self reliance, self dignity, (b) critical thinking and consciousness (c) desire and aspiration to respond to societal happenings which affect life situations and (d) inspiration and capabilities to change and transform life situation for the better.

3. SCIENCE AND TECHNOLOGY

It is accepted as pointed out by Ranis [1] that technology contributes to social and economic development of a country through goods and services. But the linkage between Science and Technology as Ranis points out is

subject to a great deal of time variance and uncertainty. It is best to find out how Science and Technology brought about the transition to modern growth in Great Britain, Germany, the U.S., Japan, the USSR and China. but the USSR and China have been left out in this discussion purely because of the author's inability to find the time to collect relevant data.

According to Ranis, Britain's early lead based on such industries as textiles, metals and brewing was developed on the basis of 'tinkering' rather than on new scientific insights. Even the smelting of iron ore presumably was done without a knowledge of the chemistry of oxidation or reduction. Caldwell [2] attributes the decline of British leadership largely to the fact that British technology was substantially "empirically-based" rather then "science-based". But Ranis points out that the explanation of Britain's relative decline to its failure to perceive the existence of a direct link between basic science and technology does not serve a useful purpose, because of the relative success of the US experience in the last half of the 19th century. The base for US technology change and its associated growth pattern was clearly "empirical" in the sense that the US exploitation of the idea of mass production with interchangeable parts, which gave it a commanding lead in the mechanical engineering industries, can also be said to have emerged from trial and error method applied to largely imported technology.

Japan represents the case of a small latecomer country that can today be definitely labelled "mature". It also developed on imported technology, but it is instructive to note that it took the Japanese relatively little time to recognize not only that imported technology had to be carefully selected but also that for maximum effectiveness, it had to be substantially adapted to local conditions. The Government spent relatively little effort or resources on the advancement of pure science as Ranis points out. Yet the quick, empirically based response of Japanese engineers and industrialists would not have been possible without a strong and well-dispersed educational base, both general and technical, which had been part of the Japanese scene from the beginning. To borrow wisely and to adapt requires as Nakayama [3]

points out, intermediate level scientific manpower, not "big science" or heavy R & D expenditures. In this sense we may detect a strong parallel with the 19th century US case: pragmatic borrowing of technology from abroad, plus extensive indigeneous technology change supported by high, well distributed levels of scientific and technical literacy.

The position in Germany in the 19th century was different from those described above. Their development was science based. They established a network of technical and scientific institutions at various levels that were to provide formal training in fields ranging from engineering and mechanics to manual arts and design. Encouragement was provided through expositions, awards, subsidies and technical advice.

From this cursory look at development in few countries it appears at first sight that one has to decide between a science based development of technological innovation or an empirically based development. But this is not the case, for as Ranis points out, for technology change to occur, something has to be "in the air" in the form of recent or past improvements in our basic understanding of the environment, even if the innovator himself is not a scientist working in a laboratory. It is not possible for innovations to develop in a society "wholly barren of science". Therefore a nation importing technology, if it is to develop should be able to borrow wisely and adapt. This can be achieved only through well distributed levels of scientific and technical literacy among its people with a strong desire to transform life situations for the better through their critical thinking. This will create an atmosphere of "science in the air" conducive to technological innovations. Since Sri Lanka has been importing technology, mostly in the form of imported machinery only, since independence, this method of development through proper training programmes may be planned . But this training programme will not be complete and effective without input, for its planning, from a study of the ancient irrigation schemes and the hydraulic engineering and the impact that colonization has had on the Sri Lankan society.

4. SCIENCE AND TECHNOLOGY DEVELOPMENT IN SRI LANKA

Three broad periods in the history of Sri Lanka have to be considered in planning a Science and Technology strategy. They are (i) the ancient history with the great irrigation schemes and the hydraulic engineering of that time (ii) the period of colonization by the Portugese, the Dutch and the British (iii) the post independence period and the beginning of imported technology.

An in-depth study of the skills in hydraulic engineering and the crafts and how they were utilized in the society in Sri Lanka at that time is necessary. It will also be necessary to identify if possible the existence of these skills in the villages in Sri Lanka at the present time.

A few remarks on the ancient engineering skills in Sri Lanka will be useful at this stage. Brohier [4] records that according to an assistant government agent in 1855: "It is possible, that in no other part of the world are there to be found within the same space the remains of so many works of irrigation which are at the same time, of such great antiquity, and of such vast magnitude as in ceylon. Probably no other country can exhibit works so numerous, and at the same time so ancient and extensive, within the same limited area, as this island". Brohier records three areas of engineering skills in these irrigation schemes namely: (i) slices placed under the bed of lakes to regulate water supply to paddy fields, constructed probably more than 2100 years ago (ii) machinery to raise water level constructed as early as 19 BC (iii) surveying and levelling.

In order to understand the changes that colonization brought about to these skills and their practise it will be necessary to study the status of Science and Technology, and the social, economic and political structure of the Portugese, the Dutch and the British at the time of colonization and the influence these had on the corresponding Sri Lankan situation. This study, it is hoped, will assist in the proper merging of the imported technology with the local skills.

After independence there has been an import of technology. It will be necessary to do a detailed study of the impact that these have had in Sri Lanka.

But before planning such a strategy after a proper study it is necessary to take few steps from a broad and general understanding of the situation in the country. One such area where this is possible is education.

5. EDUCATION IN SRI LANKA

For technological innovations to have an impact on the social and economic development of the country the society's national capacity to select proper technology and adapt it to differing environments should be increased. The calls for a high, well distributed level of scientific and technical literacy in the country. But this literacy has to be in the hands of people with self-reliance, critical thinking and consciousness, desire and aspiration to respond to society happenings which effect life situations and inspiration to transform life situation for the better. That is, our training programme in addition to imparting a technical knowledge should be so organized as to involve the participants in the programme. But the educational programme in the country is unable to play this dual role. The main reason for this is the undesirable emphasis placed on Examinations used to select people for the Civil Service. In schools as well as in the Universities students prepare to answer questions at examinations. The training aspect in which the trainees play a partecipatory and active role is minimal. This should give way to teaching situations which promote critical thinking, power of analysis and provide a forum for dialogue between different people allowing exchange and synthesis of ideas of techniques and of motivation. This change while imparting technical knowledge will at the same time ensure the progress of the participants.

As an example let us consider the situation in the Faculty of Engineering of the University of Peradeniya, in Sri Lanka. A major difficulty facing

this institution is the poor standard in physics and mathematics of the new entrants. Most of them have done relatively few or no experiments in physics in their schools. It is difficult for such students to cope with work in any laboratory in the Faculty of Engineering. Students in schools pay minimum attention to understand the subject matter but put all their effort in preparing for examination questions. They spent most of their time in tutories which prepare them for examinations. Emphasis on examination without any training in physics and mathematics cripples students' ability to analyze, critically think and to dialogue on the subject matter. This is true at all levels in schools and in the University. There are of course exceptions in schools as well as in the University. But generally this is the situation. One reason for this situation is the stiff competition to enter the University, the selection for which is through examination performance. Also for many a degree certificate is the only way to a secure and good employment. Training in technical colleges and vocational training centres has still not become as attractive as it should be.

Also in the University the situation is no better. In the Faculty of Engineering all students, about 250 in number, follow a common course during the first two years. Formal lectures are given to the whole group with almost no partecipation from the students. This only reinforces the typical way of learning practised by many students. For the practise of science an active participatory role through which critical thinking can be promoted instead of a passive one is essential. The learning situation should consciously promote exchange and synthesis of ideas, of techniques, and of motivation. Without this kind of training at the University technical colleges, and vocational training centres one cannot expect proper adaptation of imported technology to suit local conditions and the emergence of technological innovations.

This kind of training programme will require the services of teachers not only competent in Physics and Mathematics but also sensitive to the art of improving knowledge. In Sri Lanka at the moment the teaching profession is used by many only as a stepping stone to move towards a more financially

rewarding profession. This situation should be reversed.

The teaching of Physics and Mathematics should not be isolated from its relevance to local conditions. In this context the next basic resource comes to the fore, namely the natural resource. Science can seep deep into our social structure through a process of a search, analysis, and qualification of renewable sources of energy in the country. A thorough study of these resources requires a sound training in Physics and Mathematics. At the same time a study of the resources of our environment can strengthen the understanding of Physics. At this stage it is useful to draw attention to the scientific and ambitious methods aimed at conserving the abundance of water dispersed over the plains during the rains of the two monsoons in ancient Sri Lanka as recorded by Brohier. The country at this stage is called upon to understand and conserve its renewable resources as in the past.

In schools and in the Universities it is desirable as far as possible to draw attention through the teaching programme to the importance of energy and national development. The purpose would be twofold: (i) to appreciate the concepts in Physics through a practical situation (ii) to demonstrate the relevance of their studies to lives of people in the country. This can instil in them a desire to use their talents for the benefit of the society and open the possibility of a pioneering spirit in them which existed at the time of technological development in Britain and the USA.

The develop a teaching profession which while being competent in Physics has also the ability to integrate into the curriculum the natural resources of the country and is at the same time sensitive to the art of developing the students, needs the formulation of a definite programme. It can take the form of regular meetings of teachers of Physics and Mathematics from schools in certain areas with specialists in the subjects and educationists. This can be a form for the exchange and evaluation of experience and ideas.

6. CONCLUSIONS

(i) A study of the status of technology during the three broad periods of the history of Sri lanka, namely before colonization, period of colonization, period after independence will assist in the organization of training programmes in technology, development of curricula in schools and in the universities and in the formulation of development strategies.

(ii) Adequate emphasis should be given to the development of persons in all training programmes including Physics and Mathematics and it should be integrated with the teaching-learning situation.

(iii) The trend in which the teaching profession is only a stepping stone towards another profession should be reversed.

(iv) The sensitiveness of teachers to the development of students as persons should be improved. Also their ability to incorporate into the curriculum in Physics the natural resources of the country should be improved. It is necessary to evolve a programme to develop these.

ACKNOWLEDGMENT

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PHYSICS AND DEVELOPMENT IN EGYPT

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ABSTRACT

A brief review is given of the economic data relating to the development of Egypt, and of education in general with emphasis on physics education at the different teaching levels. The situation of scientific research and physics research is presented. A proposal is offered to conduct research in Egypt. I state the objectives to be realized through my Associate Membership of the ICTP.

I. ECONOMIC DATA RELATING TO THE DEVELOPMENT OF EGYPT:

1. OVERVIEW:

The geographical and demographic characteristics of Egypt delineate its basic economic problem. Although the country contains about 386,000 square miles, only a narrow strip in the Nile Valley and Delta is usable. The area of 15,000 square miles - less than 4% - is practically used. Without the Nile which flows through Egypt for about 1000 miles, the country would be part of Sahara. Crammed in the habitual area is 98% of the population, estimated at more than 45 millions giving a density of more than 3,100 per square mile. The population is growing rapidly and is estimated to have doubled since 1947.

Land reclamation has increased the cultivated area by about 5% since 1947. More extensive cultivations has to some extent moderated the effects of the deterioration in the man-land ratio but even so the cropped area has increased only from 9.1 million feddans to 10.8 million feddans (less than 20%) in the same period. Each feddan is now expected to support 3.5 persons compared to 2.1 in 1947.

These two themes, the relatively fixed amount of usable land and the rapid growth of the population will be seen as the leitmotivs in the discussion of Egypt's economic problems.

The resolution of these problems-difficult under the most favorable circumstances - is complicated by the fact that Egypt was in war since 1967. The physical infrastructure has deteriorated considerably because of inadequate investements.

2. OVERALL DEVELOPMENT, 1952-1976

a- The 1955-1965 Decade

This decade witnessed fairly rapid and sustained economic growth as well as a major structural transformation of the economey. Industry and services increased their shares of both total output and employment, and within industry the composition of output shifted infavour of intermediate goods and consumer durables. At the same time the transion was made from a free private interprise system to an economy characterised by a state planning, public ownership of modern means of production and wide-ranging adminstrative control and policy interference.

b- The 1965-1975 Decade

In the decade the economy could no longer sustain the pace of high economic performance, largely because resources were being diverted into defense and aid flows from the west inturrpted. The rate of economic growth declined steadily. Some figures about the gross demestic product (GDP) and the per capita income.

Between 1960 and 1976 the (GDP) at a market prices increased at an average annual rate of just over 5%. Much of the increase, however, was eroded by the rate of population groth, so that the per capita income improved only from about LE 65 to LE 100 (in 1965 prices) over the sixteen years period,

that is about 2.7 percent a year. This growth in per capita income occurred at an uneven rate:

- Between 1960 and 1965 the average rate was 4.2% annually.
- Between 1966-1973 it dropped to less than 1%. In 1966-1968 and 1972 there was actually a fall in real per capita income.

The present and future are not without oppertunities. There are prospects of earning from petroleum, revenues from a widened Suez Canal and increasing remittances from the Egyptian's working abroad. Other assets include the oppertunities from tourism, the cultural and political links with the capital surplus Arab countries, the location of the country (in the Middle East but well placed for European markets), and a personally well trained labor force. The Egyptian economy thus persseses considerable potential in longer terms.

After concentrating on the economy in general, I would like to throw some light on Education in general with emphasis on Physics Education in Egypt.

3- EDUCATION:

The Structure of the System:

Most Egyptian children attend school, if only for a relatively short time. In the mid-1970s more than 4 million students were on the rolls of primary schools, and about 1.9 million were intermediate and secondary students. The compulsory

education law requires all children to whom facilities are available to attend six years (will extend to 9 years) of elementary school beginning at age six. It is estimated, however, that about 20 percent of six-year-olds fail to enter primary school, and among those nominally enrolled, a number fail to attend classes with any regularity. The attrition rate from one grade to the next is high, especially among girls, many of whom complete no more than a year or two of school. Even among boys, authorities note that many fail to achieve permanent literacy. Most parents, however, have come to recognize the destrability of modern education, at least for their sons. The kuttub, a religious school attached to a mosque, has been replaced by the public primary school as the institution of mass instruction, but in many villages it continues to provide supplementary courses in religious studies.

After gaining an elementary knowledge of reading, writing, arithmetic, history, geography, science, and other subjects in six years of primary education, the student sits for the Primary Certificate Examination administered by the Ministry of Education. The number of students passing this examination has risen steadily from about 150,000 in 1967 to over 320,000 in 1972. (In 1976, 73 percent of those taking the exam. passed it.) They are then admitted to the three-year preparatory program that culminates in the General Preparatory Certificate Examination. This intermediate stage of education.

is intended to allow students to explore their tastes and aptitudes so that they can make appropriate choices at the more specialized secondary level. Observers note, however, that because students are assigned to secondary programs on the basis of examination grades, they tend to avoid experimentation with unfamiliar subjects and to concentrate on rote learning.

About 10 percent of those who begin school reach the secondary grades; in 1975 about 310,000 students (67 percent of those participating) passed the preparatory examinations. Secondary schools offer a number of curricular options in two broad categories, the general or academic and the vocational or technical. The academic student may choose either a scientific or a literary program in the second and third years. Vocational and technical secondary programs are offered in variety of trades, including commerce, and about 51 percent of the students enrolled in them in 1974-75.

About 100,000 students a year pass the examinations that complete the academic secondary program, and another 90,000 do so in vocational subjects. In both cases, this was about 70 percent of the students participating in 1974-75. In the late 1960s about two-thirds of those finishing academic secondary school continued their education. By the mid-1970s, largely because of the government's employment policy, this had grown to three in four.

The major responsibility for formal education and training lies with the Ministry of Education (MOE) and the Ministry of Higher Education (MOHE), both of which are headed by the same minister. MOE is responsible for primary, preparatory, general, and technical secondary schools and for primary teacher training. MOHE administered the higher institutions in the past but is now responsible only for postsecondary technical training. The ten universities are autonomous in their internal administration, subject only to the supervision of a Supreme Council for Universities, an advisory body chaired by the minister of higher education.

The technical institutes are more or less autonomous, forming part of the university system. They offer specialized instruction in a number of fields including commerce, industrial subjects (such as electronics), home economics, teaching (including art eduction, music education, and physical education), social work, physical therapy, and tourism. Their curriculums and physical facilities are in the process of being upgraded to university standards. A private university (the American University of Cairo) and several private institutes also exist.

Vocational training is also provided by various ministries: industry and Mineral Resources; Housing and Reconstruction; Agriculture; Health and Social Affiars. The Ministries of Health

and of Tourism also offer postsecondary technical training. In 1976 the output of people with vocational skills in the industrial and construction trades was only about 2,600 and 1,800, respectively, much less than the average annual demand projected for the 1976-86 period.

4- PHYSICS EDUCATION:

a- Physics Education In Schools (Secondary) Schools

Students starts physics education only through 3 years in secondary schools before they join the university. Before this stage, physics is taught as general science in the preperatory schools as well as chemistry. Physics subjects are emphasized starting at the secondary school. The subjects taught during the secondary school are of descriptive nature rather than an analytical one.

b- Physics Education In Universities:

Students joining the university in Medicine, pharmacy study physics for 1 year. This is more or less the same subjects studied in the secondary schools in more details and in English language. Most engineering students study physics for 2 years where they have a better chance of the physical concept in more details.

Physics students attend a four years course in the Faculty of Science. Table (1) shows the number of graduates from 1972-1981. As it could be observed from the table, the number of students reading physics in the Faculty of Science is decreasing. This could be attributed to the difficulty the graduates meet in order to get a job.

Table 1: Physics Graduates from different Faculties of Sciences, with Total Physics Graduates from Faculties of Education for comparison.

College / year	Cairo	Ein Shams	Alex.	Azhar	Assuit	Tanta	Mansoura	Kena	Menia	Zakazik	Suez Kanal	Khartoum Cairo	Aswan	Menoufia	Total	tot No. from Fac. of Ed.
1972	91	52	31	9	9										192	364
1973	64	21	19	7	12										123	330
1974	42	30	17	16	9	8									122	494
1975	40	46	13	8	15	33	13								168	553
1976	52	62	54	14	7	6	14								209	905
1977	62	47	22	9	4	7	6	8							165	934
1978	34	57	17	10	8	13	6	5	4	10		9			173	1051
1979	40	39	13	8	8	8	8	3	2	11					140	1160
1980	39	28	10	7	11	9	17	3	3	8					135	1002
1981	25	40	7	9	2	8	8	4	9	13	7		7	15	132	2001

On the other hand table 1 shows the total number of students reading physics in the Faculty of Education. As can be observed, the number of students has almost 8 folded in the last years. This is due to the lack of teacher in Egypt as well as in the petroleum producing countries that speak Arabic.

Students Standard:

The standard of the students reading physics is unfortunately degrading because of the limited Facilities avaiable. At the same time the total number students studying physics is increasing. The professorial staff in the new universities is very limited indeed. This implements the need to employ part-time professors which reduces the contact with the professor that reflects on the students standard.

In general one can say that students suffer the following:

- They can not use high mathematics.
- No demonstration experiments or education films are available.
- The students english language is poor.
- Laboratories are very poorly equipped.

M.Sc. Students:

M.Sc. in all the universities is based upon nearly 8 hours course plus a dissertation. The courses are taught for two academic semesters. Unforturately what goes for the undergraduates applies to the M.Sc. students. But in the postgraduates case, the number of students is much smaller, around 3-4 students per class.

Ph. D. Students:

Ph.D. degree is achieved through research only. It is a direct contact between the supervisor and the student.

Research in general suffers the following:

- Lack of full-time Students and supervisors.
- Poor planning and laboratory Facilities.
- Lack of technical staff for maintainence of equipments.
- Most of the research is conducted for the sake of promotion, Group research is not yet established and which seems to be difficult as in most developing countries.

Recommendations:

At this stage one might mention some of the recommendations of the Arabian carference for development of teaching physics held in Cairo in the January of 1983:

- Physics should be taught in Arabic up to the final year. Text books should be translated into Arabic. On the other hand English should be taught an independantly as a language.

- Scientific conferences should be encouraged.
- Scientific physics journals should be available.
- Warkshops to build physics equipment should be set. Also technical staff to maintain such equipment ought to be trained.
- Financial status of professonal staff should be improved.
- A reasonable professor to student ratio must be considered.
- Summer Schools and workshops in physics must increase.
- Basic courses in physics in different aniversities should be unified.
- It is recommended to have the full year system for the first and second years, then the credit hour system for the final years, where selective and compulsory courses are introduced. This is aimed to prepare the students towards applied fields such as: Nuclear Evergy, Polymers, Radiation physics, Geophysics, Health physics computer sience and Enviromental problems.
- Summer training for 3rd year students should be arranged.
- The establishment of a specialised research centers in physics such as Nuclear Energy, Solid State, Electronics or Geophysics.

- Co-operation between production sites and research groups in order to solve production problems.

5- SCIENTIFIC RESEARCH IN EGYPT:

Scientific Research in Egypt is conducted along three different axes:

1) In Universities, where most of the subjects are of academic nature. Results of limited projects could be utilized in practical fields such as those carried out in colleges of Agriculture, Engineering, Medicine and Pharmacy.

Universities includes includes 16 institute and specialized centers, besides the research conducted in the different departments in the colleges.

2) Applied projects under the supervision of the Academy of Scientific Research and Technology through 6 institutes and research centers. The Academy Sponsors as well research projects in different places.

The academy research plan is concerned with the national production as well as the major services of the country. A good adminstrative system to supervise its scheme of work was developed in 1978. This system needs further support in order to have it completely settled and enables it to widen its range of activity.

3) Specialized units in different authorities. This represent 50 research units besides research centers in industrial and agricultural organisations. These units or centers are mainly concerned with applied research and serves a particular purpose. Such centers has fullfiled many successful jobs i.e. in developing some agricultural crops.

In general research centers and institutes lacks the following :-

1. Up to date information center.
2. Coordination between the different centers in order to avoid duplication and to concenterate on National needs.
3. Technical staff required to assist the researchers.
4. Developed equipments.
5. Non pirocratic adminstration.
6. Rules organising the behavior of professional researches.
7. General National policies that creats need to such organisation.
8. Insentive that correlates between the re earch results and its outcome.
9. Supporting establishments complementary to scientific research e.g. Techno-Economical Feasibility studies, quality control and high standard consultancy establishments.

6- Physics Research:

Physics research in Egypt is almost academic and is conducted mainly in the physics departments in universities. Promotion system for the staff members from lecturar to professor is mainly dependant on the scientific work of the staff member.

Due to the poor facilities in the different departments and to the fact that staff members are fairly busy during the academic year, many of them travels abroad to places like the ICTP, in order to catch up with recent achievements.

The research projects in departments are financed through the local physics department budget which is very limited indeed.

Recently the Academy of Sciences started to sponsor some research projects in physics in the field of lazer technology and high energy physics.

II. HOW RESEACH CAN BE CONDUCTED IN EGYPT:

I think that the following proposals can push forward scientific research:

1- Full-time stoff members who are well paid relative to their society.

2- Stoff members should be forced towards group work to excute an approwed national research plan which should not be too ambitious in the begining.

3- Simple equipment whose spare parts are available should be always choosen, with highly trained technicians.

4- Sceentific literature should be aailable.

5- Contacts with external scientific world should be well organized.

6- The scientific research can include the following fields:
Conventional and non-conventional energy sources-Natural resorces-Semiconductor technology-Microprocessor technology-Environmental studies (Pollution-Food security- Housing materials.......)

III. My Contribution to the development of Egypt:

I hope that my Associate Membership would help me to fulfill the following objectives:

1- To put a new syllabus for teaching of physics in the Faculty of Science, Al Azhar University.

2- I established a research group in the field of Mossbauer spectroscopy (22 M.Sc. + 15 Ph.d). This field started to spread in our geographical region: so, I hope to establish a Regional center for Mössbauer spetroscopy at Al Azhar University in Cairo through the IAEA.

PHYSICS AND DEVELOPMENT IN ZAMBIA

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ABSTRACT

In this paper an overview of Zambia is presented by describing and furnishing data on such aspects as geography, economy, education, energy resources and scientific research. Various problems in the development of the country have been pointed out. The present state of scientific research and development is described and the role of science and technology, in general, and physics, in particular, in the development of the country has been highlighted. Broad priority areas for scientific research and development in the country have been identified.

1. GEOGRAPHY

The Republic of Zambia, a large country in south Central Africa, shares its borders with eight other countries. It is boarded on the south by Mozambique, Zimbabwe, Botswana and Namibia; on the west by Angola; on the north by Zaire and in the east by Tanzania and Malawi. It covers an area of 752614 square kilometers. For administration purposes Zambia is divided into nine provinces - Northern, Eastern, Lusaka, Southern, Western, North-Western, Copperbelt, Luapula and Central (Fig.1) - and these are subdivided into districts.

Zambia is a landlocked country. It must therefore rely on its neighbours for access to the sea. Also, it has no navigable rivers. However there are several large in-land lakes including Lake Bangweulu, Lake Tanganyika and Lake Mweru in the Northern and Luapula provinces, and Lake Kariba which forms part of the Southern border with Zimbabwe. Although not of major transportation for import, these lakes do offer a potential for commercial fishing and possibly irrigation.

Zambia is situated between a latitude of about 8^{O}S to 18^{O}S and longitude of about 23^{O}E to 33^{O}E. The climate is tropical, but for the most part, is tempered by the country's higher altitudes which range from about 950 to 1500 meters. The climate is mild for most part

of the year - the yearly average minimum temperature being about 9°C and the maximum about 32°C. Fertile soil, adequate rainfall (barring the occasional drought) and the mild climate make it possible for nearly year-round planting; however, Zambia is presently cultivating only 5% to 6% of the estimated 50% to 60% total land area considered to be immediately arable.

2. DEMOGRAPHY

The population of Zambia, increasing at an annual growth rate of 3.2% over the last decade, was estimated to be 5.83 million in mid-1980 representing in excess of 10 different tribal groups. The main languages spoken are English (the official and commercial language), Bemba, Nyanja, Tonga, Lozi, Lunda, Luvale and Kaonde with a host of local dialects. Population density as in most countries varies subtantially between the urban and rural areas, with about 40% of the total population concentrated in urban areas and particularly along the line of rail from Livingstone in the South through Lusaka to the Copperbelt towns near the Zaire border (Fig.1). The population growth in the urban areas far exceeds that in the rest of the country and results mainly from the continuing rural exodus of unskilled labourers to urban areas. As in other countries in this stage of development, this trend has produced unemployment and other social problems, as the number of new wage-earning jobs could not keep pace with this accelerated growth.

About 65% of the people of Zambia derive their living from agriculture. The mining sector employs approximately 16% of the wage earners in Zambia. The expatriate population, comprised mainly of Europeans (mostly British) and Asians, numbers approximately 80,000 which figure is down considerably from a one-time high of about 100,000. The majority of the expatriates are employed in the mines or by industries whose main commercial demands come from the mining sector.

3. ECONOMY

The Zambian economy is heavily import dependent. The foreign exchange necessary for imports is earned mainly through its mining industry. Copper alone accounts for about 80% of its foreign exchange earnings. As a result, the Zambian economy has been very vulnerable to the world copper prices and has suffered violent fluctuations due primarily to fluctuations in the copper price (see Table 1 and Fig. 2). Efforts to diversify the economy by expanding agriculture and industrial production have met with limited success. Before 1975 the fluctuations in prices tended in the long run to balance each other and the balance of payment situation was not bad. However, the rapidly increasing demand for imports due to Zambia's dependence on foreign technology and expertise, machinery, spares and a wide range of food stuffs such as wheat and more recently maize, vegetable oils and protein and dairy products and the subsequent collapse in 1975 of the copper prices sent the country under

a massive deficit in the current accounts.

The situation has not improved much since then except during 1979 when the overall balance of payment registered a surplus due to a short-term recovery in the copper prices and a significant improvement in the trade account. Presently Zambia has been undergoing great foreign exchange hardships inhibiting the imports of essential raw materials and equipment and resulting in underutilisation of its resources. Faced with the economic crisis it has been seeking finacial assistance from the IMF and other international donor agencies and had to devalue its currency, Kwacha, by 20% (at present, 1 Kwacha = U.S. $0.82).

3.1. MINING

Mining has been the most important sector in Zambian economy, which is almost entirely dependent on it for its foreign exchange earnings. It is the fourth largest copper producer in the world after the U.S.A., the U.S.S.R. and Chile. Mining as a sector of the whole economy contributed 29% to Zambia's total gross domestic product (GDP) in 1980 (Table 2). Copper alone accounted for about 80% and copper and cobalt for more than 90% of Zambia's total foreign exchange earnings with an additional 5% derived mainly from lead, zinc and tobacco (Table 3).

As a result of its heavy dependence for foreign exchange on a single item, Zambia's fortunes have always been coupled with the copper prices in the international market. Since 1966 Zambia's copper has been sold at the prevailing cash settlement price on the London Metal Exchange (LME) which has been subjected to a series of wide fluctuations. Favourable prices during the late sixties were quickly followed by sharp declines in 1971 and 1972; however, a boom in copper as well as in other commodities in 1973/74 brought record high prices throughout 1974 of K1326 per tonne, having at one point during the year reached an all-time high of K2000 per tonne.

The boom was short-lived as in 1975 the price dipped to an average of K794 per tonne due to decrease in demand. Over the next three years (1976-78) the prices did not improve much due to overstocking, the average annual selling price for the three years being slightly in excess of K1000 per tonne in spite of an improvement in the world consumption. The year 1979 witnessed a recovery in the copper price followed quickly by a long period of decline in the prices, which have started picking up only recently.

3.2. AGRICULTURE

The climatic and topographical conditions of Zambia are such that it has a recognised vast potential for agriculture. 50% to 60% of the total land area of Zambia is estimated to be immediately arable, but only 5% to 6% is being cultivated presently. Since independence self-sufficiency in food production has been a primary goal in the government's various development plans.

Unfortunately, progress in the realization of this goal has been slow due to various reasons like almost complete dependence on copper, rural exodus, shortage of skilled manpower, lack of availability of proper equipment and spares, shortage of foreign exchange and lack of irrigation facilities.

The principal cash crop as well as staple food for the general population is maize. Other food stuffs actively produced include beef, pork, poultry, wheat, sugar and groundnuts. Zambia also produces tobacco which is the second largest cash crop and cotton (Table 4).

3.3 MANUFACTURING

Manufacturing as a contributing sector to Zambia's economy is the youngest of the major economic activities in term of development, in that the mining and agricultural sectors were reasonably well established by the time of independence whereas the increasing local demand for manufactured goods was being met largely through imports. Under the Central African Federation scheme, Zambia provided the raw materials while Zimbabwe provided the finished goods. Under the protective umbrella of colonial rule, there was no apparent need or incentive to expand local manufacturing capabilities.

With independence in 1964, a combination of national pride and economic necessity resulted in a substantial growth in manufacturing output. Up until 1970, the manufacturing sector grew at an annual rate of 15% in real terms. Growth was achieved in virtually all industries but particular successes were achieved in chemicals, textiles, clothing,

manufactured food-stuffs, beverages and tobacco. By 1970, the manufacturing sector's contribution (exclusive of copper refining which is classified as part of mining output) to the total GDP was 11% matching that of the agricultural sector. In 1971, the sector's share in total GDP suspassed that of agriculture, a trend that continued until 1976 when the roles were once again reversed. Since 1976 manufacturing has lagged marginally behind agriculture as the third major sector.

The early growth of the manufacturing sector was principally attributable to efforts at import substitution as it relates to supplying the mining sector. Further growth was curtailed due to the manufacturing sector's dependence on imports of both raw material for the production process and plant and equipment on a regular replacement basis to maintain production levels. Zambia's foreign exchange shortages have severely constrained such imports and consequently curtailed production. Since 1975 the manufacturing sector has been on the decline (Table 2). Nevertheless, the manufacturing sector has been an important sector contributing significantly to the GDP. After mining, the manufacturing sector and the agricultural sector have contributed maximum to the GDP.

Among the major manufacturing operations presently in Zambia are the following: two breweries, a sugar refinery, edible oil products, Kafue textiles (manufacturing clothes), Kabwe Industrial Fabrics (making sacks and ropes), Nitrogen Chemicals of Zambia (making ammonium nitrate

fertilizers), Kafironda Ltd (producing explosives for the mines), Chilanga Cement Factories (making the country self-sufficient in cement products), the Kapiri Mposhi glass bottle factory, Livingstone Motor Assemblers (assembling cars). Also included are the Dunlop car tyre plant, sulphuric acid plants (for the mines), Zamefa (making semi-manufactured copper products), bus assembly, a Bata shoe factory and a variety of electrical and mechanical engineering companies producing goods for the copper mines.

4. EDUCATION

Due to the continuing shortage of indigenous skilled manpower Zambia has been facing ever since independence, education assumes an specially important place both in obvious development and in the long-term benefit. A significant progress has been achieved in this area, but a lot has to be still achieved.

At the time of independence Zambia with a population of 3.6 million had a total of only 100 University graduates and a little more than 1000 with the cambridge Overseas School Certificate. Less than one in three of the adult population had ever been to school and one in thirty had completed a full primary course. The country's new university was still at the discussion stage and very few Zambians were being trained for the professions or for skilled occupations. Since 1964 the Ministry of Education has launched an ambitious programme which has resulted in a steady increase in the number of student enrolment at all stages. In

1979, there were 2786 primary schools, 125 secondary schools, 14 teacher training colleges and one University in the country. The total number of student enrolment for this year in the primary schools was 996,597 (as against 378,417 in 1964), in the secondary schools 91795 (as against 13853 in 1964) and in the teacher training colleges was 4406.

The present interim structure of education in Zambia is depicted in Figure 3. The primary education consists of seven years of continuous education, the junior secondary of two years and the senior secondary of three years. The students are selected at the end of grade 7 to embark on the second phase of the basic education. It has been approved that in the final structure the seven years of primary and two years of junior secondary education will be merged to give rise to continuous 9 years of basic education. However, it is not possible to follow this structure at present due to the limited facilities in secondary ~~secondary~~ education. The 12 years of schooling prepares the student to a level equivalent to General Certificate of Education of U.K. examinations.

The University of Zambia, the only university in the country, has its main campus at Lusaka. It essentially comprises of the following Schools: Humanities and Social Sciences, Natural Sciences, Engineering, Medicine, Mining, Law, Education, Agricultural Sciences, Environmental Studies and Industrial and Business studies. The Schools of Industrial and Business Studies, and Environmental Studies are situated at the Ndola campus of the University.

There is a third campus of the University at Solwezi. Besides, there are four research institutions - Education Research Bureau, Institute for African Studies, Institute of Human relations and Rural Development Studies Bureau - and one Centre for Continuing Education. The student enrolment of the unviersity for the current year 1982/83 is 4088.

In spite of a significant expansion of education since independence, a lot still remains to be achieved. Education is free for all in principle, but only a very small fraction of the population is able to acquire higher education due to limited resources and the high failure rates at various stages of education. Only 15-20% of the students in grade 7 are able to get admission in grade 8. There is a further screening of about 50% at the end of the junior secondary level and finally only about 10% of the students in the senior secondary class are able to get admission in the university. Thus, overall, only less than 1% of the students enrolled in the primary manage to procure a seat for the university education. This is a pathetic situation, particularly for a country seriously plagued by the shortage of highly skilled manpower.

5. TRANSPORT AND COMMUNICATIONS

Zambia, being landlocked, has had to rely on the cooperation of its neighbours in providing access to the sea. Prior to independence, Zambia's main trade route was southward to

Rhodesia (now Zimbabwe) and out through Mozambique to the ports of Beira and Maputo. With Zambia's independence in 1964 and Rhodesia's unilateral declaration of independence shortly thereafter, increased tension between these two states led to a decline in bilateral trade with the eventual closure of the Zambian-Rhodesian border in 1973 forcing Zambia to utilize alternative routes.

The Benguela Railway passing from Zambia's Copperbelt through Zaire and out through Angola to the port of Lobito then became the most viable route. At the same time, the People's Republic of China began its work on the Tanzania-Zambia Railway (TAZARA) linking Zambia's rail system with the port of Dar-es-Salàam. The project was completed in 1975.

In the meantime utilization of the Benguela Railway was curtailed by the civil war which erupted in Angola causing a continuing disruption of services followed by the eventual closure in 1975 due to guerrilla activities staged against strategic positions along the rail line. This meant that the only route open was the road link to Dar-es-Salaam.

The completion of TAZARA was greeted with considerable expectations. However, by the end of 1978, having been plagued by a series of accidents and maintenance delays coupled with continuing congestion at the port of Dar-es-Salaam the operating capacity has been much below expectation.

In october 1978, faced with the possibility of not being able to move the essential exports and imports and especially fertilizer required for that year's maize planting, President Kaunda announced the opening of the sourthern route through Rhodesia which had been closed since 1973.

The transport sector continues to have problems as the limited supply of equipment and spares cannot keep pace with the maintenance requirements of both rail and road transport, and Zambia, not having its own port, must continue to rely on the cooperation of its neighbours sharing in the problems of port congestion.

As of 1979, there were some 5500 km of bitumenised roads and approximately 8000 km of gravel roads. Construction of new roads and maintenance work on the existing network has not been adequate due to shortage of funds.

An 8 inch pipeline was completed in 1968 to carry refined oil from Dar-es-Salaam to Ndola. Prior to that, road transport was the only means by which petrol could be brought into Zambia. With the completion of the Indeni oil refinery at Ndola in 1973, the pipeline was converted to carry crude feed stock.

The telecommunication services of the country are gradually improving. As per the year ended 31st March 1982, there was an equipped capacity of 55,130 telephone lines and 32,065 working lines in the country. There were 37 automatic and 19 manual exchanges and 26 radio telephone offices. For telex, equipped capacity was 2048 and working lines were 1436.

The postal services both inland and external have been rather erratic. There are a total of 160 post-offices in the country.

6. ENERGY

Apart from woodfuels, which is mainly used in house-hold, Zambia relies on hydroelectricity, coal and oil for almost all of its energy requirements. Before 1965 nearly all the energy supplies except woodfuels originated from, or were transported through, what is now Zimbabwe. Since 1965 Zambia has moved from complete dependence on energy imports to a high degree of self-sufficiency. At present the country has abundant resources of hydropower, coal and woodfuels. But the country has no proven petroleum deposits and all petroleum products are therefore imported.

Hydropower is the most important energy resource of the country. If woodfuels are disregarded, hydroelectricity makes up approximately 60% of the energy supplies. Zambia is a net exporter of hydroelectricity to Zimbabwe. Production comes principally from the Kafue Gorge and Victoria Falls plants operated by Zambia Electric Supply Corporation (ZESCO) and by the Kariba North and South Bank stations operated by the Central African Power Corporation (CAPCO) jointly owned by Zambia and Zimbabwe. The total estimated hydroelectic potential of the country is 4000 MW and the present installed hydroelectric capacity in Zambia of 1608 MW is well in excess of the current domestic and export demand of 1308 MW. Based on the future forecasts including possible electrification of the mines and the rural

electrification programmes, it is likely to meet the country's needs upto nearly the end of this century.

At the time of independence, all of Zambia's coal requirements were met by imports from Zimbabwe. Domestic production of coal began in 1965 and over the last decade Zambia has been almost self sufficient in coal. Disregarding the woodfuels, today coal contributes approximately 12% of total energy supplies. The only active mine is Maamba Collieries and despite its unprofitability caused by marked fluctuations in production levels, high production costs arising from the use of obsolete equipment, inadequate prices and the low grade of its coal deposits, there have been substantial ~~range~~ savings in foreign exchange. Development programmes, including assistance from the African Development Bank and the World Bank, are underway to increase production levels and improve overall profitability. The total proven reserves of coal at Maamba are about 58 million tonnes which are sufficient for over 40 years at the designed production capacity for the mines of 1.2 million tonnes per annum. The current production rate at Maamba is 610,000 tonnes per year or about 51% of the designed rate.

Firewood and charcoal are the major household fuels in the rural and urban areas. Excessive cutting of trees for charcoal production has been the main cause of localized woodfuel shortages specially in the densely populated areas.

In terms of overall energy requirements, oil makes up approximately 26% (16.5% if woodfuel is also counted). This represents no significant change over the last five years due to the government's concerted efforts to cut oil imports in the wake of a rapidly increasing fuel import bill. Since 1974 the cost of oil inpurt has risen five-fold approximately despite virtually no increase in the volume of oil imported. The country last year imported 748,150 tonnes of crude oil amounting to $213 million which was about 20% of its total import bill.

The energy demand and consumption pattern of Zambia are summarised in tables 5 and 6. Zambia's commercial energy demand depends largely on the needs of the copper mining sector, which is the main foreign exchange earner for the country. In 1981, the mining sector alone consumed (out of the total energy demand in the country) over 74% of electricity, 52% of coal, 94% of fuel oil and about 24% of diesel oil.

6.1. ALTERNATIVE ENERGY SOURCES

Though alternative energy resources seem to hold promise, specially in relation to rural development projects, research in alternative energy is still in infancy in Zambia. Some work in solar, wind and biomass is going on at the University of Zambia and the National Council of Scientific Research, but in the absence of a comprehensive policy for the development of alternative energy resources based on consideration of the various technical, economical and social aspects, the efforts remain isolated and uncoordinated. National Energy Council has been assigned, the job of planning and coordination in the energy sector, but it is not yet fully operative.

6.1.1. SOLAR

Zambia is situated between 8^oS and 18^oS latitude and at a height from about 950 to 1500 meters. The Meteorological Department has a sizeable network of 34 climatological stations in the country, but most of them are ill equipped. Zambia is endowed with plenty of sunshine. Yearly average solar insolation over most areas is about 5200 Whm^{-2} day^{-1}. In the South-western region near Victoria Falls the mean annual radiation level is about 6000 Whm^{-2} day^{-1}, which is one of the highest in the world. The number of sunshine hours varies between 2600 and 3000 hours per day. Seasonal variations in insolation levels occur with a peak in October and November.

Zambia is rich in mineral wealth. It produces metals that are often used for manufacturing devices for utilization of solar energy. For example, Zambia is a big exporter of copper which is commonly used for manufacturing solar collectors. It also produces cobalt and zinc which are also sometimes used for making solar collectors. With good solar insolation and the locally available mineral wealth, Zambia is well placed for the exploitation of solar energy. However, due to the availability of cheap hydro-electricity in urban areas, solar energy will find its applications mostly in rural areas. Possible applications of solar energy in Zambia include, on the one hand, water heating, sun drying →

of grains, vegetables and fish using the simpler solar energy technologies, and, on the other hand, applications of photovoltaics to water pumping, communications, etc., in remote areas.

6.1.2 WIND

South-easterly winds which dominate Zambian wind patterns from early August until the end of October have better energy characteristics than the more erratic north-westerly winds of the wet season. Technology Development and Advisory Unit (TDAU) of the University of Zambia has done a few wind energy surveys. It has identified a simple windpump for testing. If the tests are found successful it plans to promote local manufacture of the windpumps on a commercial basis.

Horizontal axis windmills have been used in the past for pumping water on remote commercial farms. About 100 multiblade windpumps are still in operation around Lusaka.

6.1.3 BIOGAS

No specific assessment of animal and agricultural wastes as feedstock for biogas generation has been made in Zambia. But some parts of the country have a relatively high concentration of livestock and the potential for biogas development exists in these areas. Cow dung is sometimes used as a fuel in some settlements near Mongu in the Northwestern province. The NCSR collaborates with counterpart institutions in Tanzania, Uganda and Kenya on a regional biogas research program, funded in parts by the Commonwealth Science Council. NCSR has installed a biogas generator which operates on cow dung

at its Chalimbana Farm near Lusaka. The unit currently supplies the cooking fuel requirements of 3 households on the farm. The next steps are to reduce the cost through the use of cheaper construction materials and to collaborate with the Zambian Agricultural Development Ltd in installing a second experimental unit at the Nkumba piggery. Current demand for biogas is small but research and development work should be continued in this program.

6.1.4 BAGASSE

Nakambala Sugar Mill(ZSC) produces about 270,000 tonnes of bagasse per year equivalent to 30% of the annual crushed cane output (900,000 tonnes per year). Current use of the fuel is for onsite steam generation. The mill utilizes about 180,000 tonnes of bagasse at present, but plans to expand its sugar refinery to use part of the remaining 90,000 tonnes of bagasse. No other major new demand for bagasse fuel is expected.

6.1.5 GEOTHERMAL

Despite the relatively large number of hot springs (about 100) in the absence of volcanic activity, the prospects for locating high temperature geothermal steam are poor in Zambia. Preliminary studies indicate that the geothermal gradient in basement rocks in Zambia is between 23°C and 50°C per kilometer of depth. Hence viable working temperatures of 150 - 370°C may occur only at depth exceeding 8km. This implies low prospects for large scale economic utilization of the geothermal heat for power generation.

7. SCIENTIFIC RESEARCH

The National Council for Scientific Research (NCSR) is the highest national scientific body in the country. It was established in 1967 with a view to promoting, strengthening and coordinating the scientific and technological research and development in the country, and also advising the government on priorities in this area. The work of the NCSR has been mainly concentrating on agriculture, natural resources and some industrial fields. The Council has the following research units: (1) Animal productivity (2) Buildings and Ceramics Research (3) Environmental Research (4) Food Technology Research (5) Pest Research (6) Radioisotopes Research (7) Tree Improvement Research (8) Water Resources Research and (9) Industrial Minerals Research. In addition the Council also has units to provide technical services in Instrumentation and Materials Testing.

The Council has limited resources in terms of equipment and indigenous skilled manpower. Therefore the research work is on a very modest scale and limited to a few fields that are relevant to the needs of the country. In physics work is mainly concentrating on the applications of nuclear physics to various fields. The Council has been running a radioactive research programme which comprises research activities to adopt or develop processes for recovery of uranium and other radioactive minerals from Zambian ores and to promote peaceful uses of nuclear techniques in research, industry, agriculture and medicine. The staff engaged have fruitful contacts with some of the companies engaged in uranium prospecting in Zambia,

the Geological Survey and with the physics and chemistry departments of the University of Zambia. The Council also started in 1980 two projects on alternative energy, one on the biogas and the other on solar water heater.

Besides its R&D programme the Council also has the staff-development programme aimed at preparing highly trained indigenous manpower by sponsoring candidates for higher education. It also organises and supports science popularisation programmes to create public interest and awareness to science and technology.

University of Zambia is the other important place of scientific research activity in the country. Here, too, due to the lack of adequate equipment and indigenous skilled manpower the research projects are modest. The university sponsors research projects that are relevant to the needs of the country. Currently research projects are going on in the fields of agriculture, animal husbandry and dairy products, biochemistry, chemistry, biology, physics, mathematics, civil engineering, electrical engineering, industrial technology and mechanical engineering, medical sciences, geology, mining and metallurgy.

Due to the shortage of staff, the teaching and research efforts of the physics department of the university are mainly directed towards solid state physics, electronics and nuclear physics.

The mining industry of the country has been facing the task of developing an economical method for the separation of cobalt from copper ore. In response to this national need, the department has been running the research project "Magnetic separation of cobalt", for the past few years. Another research project "Uranium detection using slow neutrons" has been going on to meet the national need for the development of nuclear techniques for detection of the suspected deposits of uranium in some regions of the country. In solar energy, work is being done in the measurement and estimation of solar irradiance, study of selective surfaces and photovoltaics.

Besides the NCSR and the University of Zambia, research and development work in earth sciences has been going on at the Geological Survey Department of the Government of Zambia and at the Zambia Consolidated Copper Mines (ZCCM), the only mining company in the country.

8. ROLE OF SCIENTIFIC RESEARCH IN DEVELOPMENT

The role of science and technology in present-day developments can hardly be overemphasized. The phenomenal developments in the post-war era have all been due to important breakthroughs at various scientific fronts. We are at the brink of witnessing yet more revolutions in scientific fields like computers and genetics. Of course, a majority of the countries of the world, the so-called developing countries, will not be able

participate in these revolutions for quite some time, as they are still struggling to provide the basic amenities to their population; however, this does not minimise the importance of science and technology for them. Scientific research is necessary for consolidation and continuation of any growth process as it provides the necessary tool for solving the peculiar problems and challenges coming in the way of development. In fact, the developing countries need to adopt a rational policy of vigorous scientific activity which alone can enable them to reduce the ever-widening gap between the developing and the developed nations. In this regard the developing countries are caught up in a vicious circle. They have limited resources for carrying out the scientific activity. The poor input in scientific activity, in turn, results in inefficiency, poor production, underutilization of the resources and inhibition of the growth process. So it requires more effort on their part to pool up their resources and use them to enhance their scientific activity in carefully chosen areas of priority.

Research and education in Physics, while being part of the overall scientific activity, is particularly important. Principles of physics form the basis of understanding of various phenomena in other branches of science, and developments in physics have led to corresponding developments in engineering, medicine, agriculture, earth sciences and

other natural sciences. Though the studies and development in different disciplines of sciences have become increasingly more interrelated these days, the development in physics will specially result in the growth of other scientific disciplines.

Zambia is endowed with many natural resources both renewable and non-renewable which are capable of being developed and a number of them have already played a major role in the development of the country. Many of these resources remain unexplored, unexploited and underutilized not to mention many that are undiscovered. Their meaningful exploitation depends very considerably upon advances in and application of science and technology.

Mining is the most important sector in Zambian economy. Zambia is the fourth largest copper producer in the world and only next to Zaire in the production of the strategic metal cobalt. It also produces zinc and lead. There are possibilities of uranium deposits and oil, too, in the country for which the prospecting has been going on.

The new and latest prospecting methods, geophysical and geochemical, and the more efficient mining techniques have to be employed to tap this vast reservoir economically.

As has been emphasized earlier, hydroelectricity has already been playing a vital role in the energy supply of Zambia. However, a vast amount of hydroelectric potential still remains untapped. The development of this potential is impossible without recourse to science and technology.

Water in some parts of Zambia is scanty and its relative unavailability constitutes the principal factor limiting various forms of human endeavours. Many parts of Zambia depend on underground water resources. The use of modern scientific and technological methods and aerial photography suplemented by modern well-recording procedures and improved drilling equipment can now permit better indentification, assessment and development of underground water resources.

Fish is a valuable natural resource in terms of food and as a source of revenue. Development of the fisheries could present an easy and cheap way of meeting the food requirements of the people and make immense contribution to the solution of the problem of protein-calorie malnutrition. The proper utilization of this resource again depends on adequate scientific knowledge of the fish of the country, their growth characteristics, population dynamics, general ecology and biology.

The science of forestry has an important role to play in the development of a country. It helps in protecting the natural environment on the one hand and provides wood-fuels and biomass for domestic and industrial use in the other. The full exploitation of this resource depends on scientific and technological advances in several related fields like forest genetics and ecology, tree physiology, studies of wood diseases and quality, coupled with remote sensing techniques for natural resources survey.

Agriculture is another important sector in Zambia's economy and there is great scope for its development. Presently Zambia is cultivating only about 5% to 6% of the estimated 50% to 60% of the total land area considered to be immediately arable. The main problems in its development are the lack of modern equipment, inadequate irrigation, peculiar crop and animal diseases. Science allied to technology can and already plays a crucial role in tackling the various problems. For example, the development and utilization of solar and wind energy could help in alleviating the problem of inadequate irrigation. In fact, the combined efforts of agriculturists, soil chemists, physicists, biologists, surveyors, climatologists and engineers is required for understanding and tackling the various associated problems and enabling an overall improvement. Associated with agriculture is the livestock industry and it requires the study of animal genetics and breeding and the various animal diseases for its improvement.

Improvement of public health is of prime concern in any society. The developments in medical sciences have been almost exclusively through developments in chemistry, biology and ~~nuclear and radiation~~ physics. λ Natural sciences will continue to play key roles in its further development, too. In addition many of the human diseases are due predominantly to particular environmental conditions. Zambian environment provides conditions for many parasitic diseases.

λ The advancements in biology and chemistry have enabled the studies of human anatomy and physiology, and physics has provided many powerful diagnostic and therapeutic tools through the use of x-rays, radioisotopes, etc

Malaria, bilharzia, sleeping sickness and protein calorie malnutrition are some of the diseases which are impediment to the development of the country. The effective fight against these calls for an integrated scientific and technological assault.

Transport and communication is an important sector which is often neglected. An efficient transport and communication system is necessary for rapid economic and social development in any country. It links all the other sectors of economy and has profound influence in almost every sphere of life.

Road transport plays a vital role in linking widely scattered rural areas. In the construction of roads and railways, the problems of structural designs and constructional materials are to be considered together with peculiar ground conditions and climate. These are highly technical matters and require the combined efforts of the engineers, the geologists, the physicists, the chemists, the geographers and the meteorologists for their solution.

Adequate communications are one of the fundamental differences between developed and developing societies. About 75% of all the telephones of the world are concentrated only in eight countries of the world. Africa continent with one third of the countries of the world has only 1% of the world's telephones. Well developed communications are indispensable not only as a support to all productive sectors of the economy but also because they create an environment suitable to new investment. They greatly help in sustaining, facilitating

and triggering development. Their indirect economic and social benefits mostly remain unrecognised but are worth many times what they cost. In an energy expensive world an efficient telecommunication system gains further importance as it helps to reduce the consumption of energy by reducing strain on the transport sector and saving time. Communications also greatly help in the development of rural areas by stimulating the growth of industries, agriculture and business, and thus stop the rural exodus, a problem being faced all over the world.

The parallel development of telecommunications and computers has brought the world to the brink of an information revolution. The phenomenal developments taking place at present in such fields as optical fibres, computer communications, integrated services and digital networks are going to change our overall capabilities before the end of this century. The information revolution could put anyone in the world in touch not only with anyone else but with a choice of services and information no one city can offer, thus bringing about the much-needed process of decentralization on our planet. In recognition of the important role of communications in development, the United Nations has declared the year 1983 as the World Communication Year. All the developments in telecommunications have been mainly through various developments in Physics. Highly skilled manpower is necessary to maintain and improve high-tech communication system.

In the wake of the depleting fossil fuels of the world, the development of alternative energy resources has become very important to ensure continued supply of energy needs of a country. The proper development and exploitation of these is impossible without the help of science and technology. Biomass, solar, wind and hydroelectric power hold lot of promise for future applications in many countries including Zambia. Physics and engineering play a vital role in the utilization of solar energy. Solar collectors and solar cells are the two main means of harnessing solar power. Spectrally selective surfaces play an important role in the solar collector technology. The physics of materials, in particular, the understanding of the electronic structure of materials enables one to modify the properties of substances in desired ways, and hence prepare better and more efficient slective surface. Physics has already played a key role in the development of solar cells, too. Further developments in this area will again be impossible without more research and understanding in the physics of semiconducting materials. Similarly, the exploitation and full utilization of wind energy is not possible without the development and application of the principles of aerodynamics and that of biomass energy without recourse to chemistry and chemical engineering.

9. CONCLUSION

Continuous scientific research activity is necessary for the sustenance and continuation of the development process of any nation. The developing countries, having very limited resources as input to their scientific activity, must set their priorities very carefully keeping in view their peculiar conditions, natural resources and environment. Zambia has abundant natural resources and has great potential for development. In view of its conditions, the following broad priority areas can be identified:

1) The shortage of indigenous highly skilled manpower has been a great obstacle in the development of the country. Top priority must be given for science education at all levels, particularly the education at the university level needs fast expansion.

2) To develop and make full utilization of the natural resources of the country, relevant scientific research activities should be continued and intensified in the fields of earth sciences, remote sensing, agriculture and livestock, environmental sciences, forestry, fisheries, engineering and natural sciences.

3) In physics, the following priority areas based on the country's needs are identified:

   (a) Solid state physics and its materials science aspect such as characterization of materials using x-ray diffraction and x-ray fluorescence techniques, new materials, etc., for use in the country's mining industry, materials for solar energy utilization through selective surfaces and photovoltaics, etc.

b) Nuclear physics and its applications to uranium prospecting, medicine and agriculture.

c) Applications of micro-electronics and computers to various diverse disciplines such as communication, aviation, data processing, financial and business institutions.

d) Geophysics and geophysical techniques for use in prospecting.

ACKNOWLEDGEMENTS:

The author would like to thank Professor A.F. Fort for going through the manuscript and giving his valuable comments.

TABLE1. AVERAGE ANNUAL COPPER PRICES FOR THE PERIOD 1970/1982

(Electrolytic wire bars cash prices on the London Metal Exchange)

Year	Market Price (Kwacha per tonne)	Index of Copper Prices (1970-100)	International Purchaing Power of copper Index (1970-100)
1970	1010	100	100,0
1971	767	75,9	72,0
1972	764	75,6	67,9
1973	1156	114,5	90,7
1974	1326	131,3	83,8
1975	794	78,6	40,5
1976	1007	99,7	46,0
1977	1016	100,6	40,5
1978	1090	107,9	35,9
1979	1572	150,7	41,6
1980	1719	170,2	35,0
1981	1514	149,1	31,0
1982	1435	144,1	25,5

TABLE 2: GDP ECONOMICAL ACTIVITY AT CONSTANT (1970) PRICES (K MILLIONS)

Kind of Economic Activity	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Agriculture	139.4	145.6	143.9	150.5	157.0	166.9	168.2	169.0	153.4	165.5
Mining	415.8	478.1	463.1	474.3	427.9	503.2	469.7	504.8	401.3	396.1
Manufacturing	144.3	162.7	165.4	178.9	157.6	151.9	141.4	152.0	151.9	158.9
Electricity Gas and Water	23.5	31.4	32.5	46.0	48.9	52.6	57.8	58.3	62.6	66.7
Construction	88.9	94.3	99.9	114.5	138.5	99.5	90.4	82.0	77.6	68.6
Wholesale and Retail Trade Hotels and Restautants	129.5	141.8	130.0	147.9	123.9	127.2	114.5	114.9	93.0	112.9
Transport Communications and Storage	58.8	54.6	51.7	54.6	57.6	67.0	61.5	62.1	64.3	67.1
Financial Institutions Real Estate and Bus. Services	99.2	103.2	121.3	119.5	132.9	136.4	125.9	121.9	128.0	123.7
Comunity Social and Personal Services	158.1	163.5	159.4	172.6	180.6	188.4	190.0	191.0	188.6	189.3
Import Duties	29.4	29.9	24.8	28.8	26.9	20.1	16.0	12.0	11.5	13.0
Less Imputed Bank Service Charges	10.3	10.9	14.0	13.7	13.6	13.1	11.0	9.2	10.1	8.1
Total Gross Domestic Product	1276.6	1394.2	1378.1	1473.9	1438.1	1500.1	1424.4	1458.8	1322.1	1354.7

SOURCE: MONTHLY DIGEST OF STATISTICS, CENTRAL STATISTICAL OFFICE LUSAKA.

TABLE 3 MINERAL PRODUCTION (1000 TOnnes)

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Copper	633.4	698.0	681.2	702.1	640.3	712.9	657.5	643.0	588.3	610.4
Zinc	57.0	55.9	53.5	58.3	46.8	37.1	37.1	42.5	38. 2	34.3
Lead	27.7	25.9	25.0	24.5	19.1	13.5	13.3	12.7	12. 8	11.2
Coal	812.1	936.5	940.1	809.5	813.9	762.0	708.1	615.1	598.5	600.0
Cobalt	2.1	2 .1	1.9	2.0	1.8	1.6	1.7	1.6	3.3	3 .3

Source: MONTHLY DIGEST OF STATISTICS, Central Statistical Office, LUSAKA

Value of Mineral Production (K Millions)

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Copper	441.7	479.8	739.1	876.7	455.3	633.7	557.8	557.4	825.4	942.8
Zinc	11.1	13.7	16.1	26.4	19.6	17.2	22.5	17.2	20.7	16.8
Lead	4.2	4.7	5.7	8.0	3.6	3.0	5.7	5.5	11.2	6.1
Coal	6.8	7.9	8.7	7.9	9.6	12.0	14.4	15.9	15.2	17.5
Cobalt	4.6	6.9	8.1	9 .5	9.7	10.8	19.1	35.3	139.1	130.4
Other	3.4	7.6	7.6	7.7	6.7	10.6	14.4	11.3	23.9	39.6

Source: Monthly Digest of Statistics, Central Statistical Office, LUSAKA.

TABLE 4 MARKETED AGRICULTURAL OUTPUT (TONNES)

	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81
Maize	251,190	124,920	372,330	373,030	386,100	584,190	250,060	696,060	581,670	335,970	383,230
Tobacco Virginia Flue-Cured	4,805	6,248	5,544	6,222	6,201	6,466	6,115	5,588	3,704	4,591	4,127
Burley	255	389	385	471	430	502	212	312	264	381	554
Sugar Cane	322,000	331,000	397,000	488,000	570,000	768,000	780,000	691,000	775,000	888,000	930,000
Cotton	5,446	12,675	8,349	5,225	2,173	2,602	3,885	8,928	8,430	14,916	23,000
Soya Beans	-	-	-	-	-	-	1,096	1,252	1,180	1,300	3,420
Sun flower	-	-	-	1,000	3,500	6,450	16,100	13,300	7,550	11,900	17,250
Rice	-	-	-	-	-	-	1,785	1,835	1,956	1,850	2,104
Ground-Nuts	3,600	6,776	6,512	3,216	3,624	6,496	9,464	7,464	2,232	2,736	2,032
Wheat	-	-	-	-	-	-	3,948	5,323	4,541	6,528	6,966

Source: Monthly Digest of Statistics, Central Statistical Office, LUSAKA.

TABLE 5. ENERGY DEMAND BY SOURCE 1981

Source	'000 TOE*	%
Imports		
Petroleum	748**	16.5
Coke	60	1.3
Sub Total	808	17.8
Indigenuos		
Hydropower	1365***	30.4
Coal	274	6.1
Bagasse	48	1.1
Wood-fuel charcoal and Firewood	2000****	44.6
	4495	100.0

* 1 to e = 39.68 million Bt u

** including exports and refinery fuel own-use/loss.

*** excludes exports to Zimbabwe

**** based on $0.85 m^3$ per capital consumption; and a conversion factor of 0.3 toe per m^3 of wood.

TABLE 6 SECTORAL PATTERN OF ENERGY CONSUMPTION (1980/81)

(percent)

SECTOR	PETROLUEM	COKE	COAL	ELECTRICITY	WOODFUEL	BAGASSE
Mining	37	100	52	74	6	-
Industry	18	-	48	18	-	100
Transport	35	-	-	-	-	-
Agriculture	1	-	-	n.a*	-	-
Others (including household)	9	-	-	8	94	
Total	100	100	100	100	100	100

* power demand in this sector is insignificant because of the small size of agrobased industries.

Fig.1

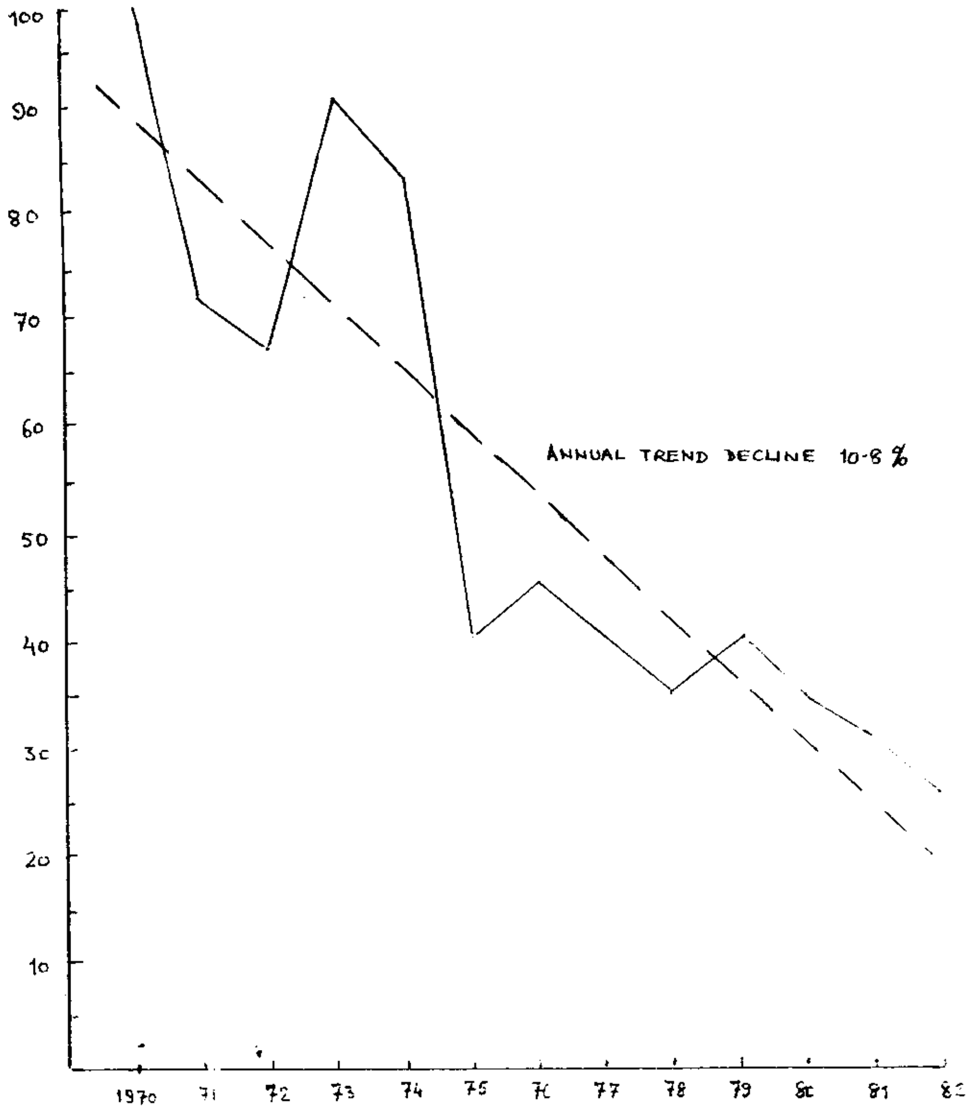
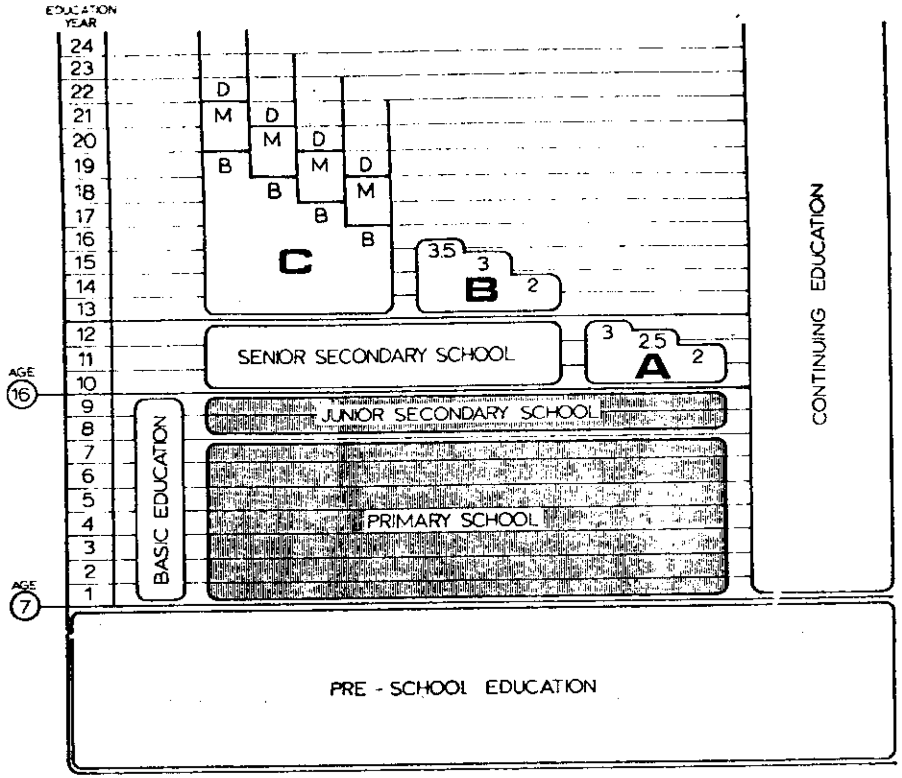


Fig.2

Copper prices in real terms, 1970-1982
Index numbers 1970 = 100

Interim structure of education



NOTES

A Various vocational programmes, e.g., Trades, Nursing, Teacher Training, etc., leading to a certificate.

B Various programmes, e.g., Agriculture, Technology, Commerce, Nursing, etc., leading usually to a diploma.

C University degree:
- D = Doctorate
- M = Master
- B = Bachelor: 4 years – Ordinary.
  - 5 years – Engineering, Agriculture, etc.
  - 6 years – Veterinary Science.
  - 7 years – Medicine.

NB
In A and B there are also some courses which take less than 2 years.
From primary to senior secondary an education year represents a grade.

Fig.3

PHYSICS AND DEVELOPMENT IN ARGENTINA

Alejandro A. Hnilo
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1. Introduction

Argentina is situated in the southern part of South America. It is boarded on the west by Chile, on the north by Bolivia, Paraguay and Brazil, on the east by Brazil, Uruguay and the Atlantic Ocean.

It is a federal republic composed of 22 member states, a federal territory and the Capital District.

Argentina became independent from Spain in 1816, and promulgated its definitive Constitution in 1853. The official language is Spanish, the religion is predominantly Roman Catholic, even though religious freedom is not only traditional in Argentine society but guaranteed by the Constitution.

Argentina's area is 2.8 million square kilometers, equivalent to all Western Europe or India. Western Europe is densely populated and India has 730 million inhabitants, while Argentina, on the contrary, has only 28 million inhabitants, and nearly 10 million of them live in the capital, Buenos Aires. This asymmetry has historical origins, and is probably the strongest problem for achieving a harmonic development.

2. Economic data

Argentina produces a wide variety of goods in its vaste territory. All sorts of food (mainly meat, cereals and fruits) also tobacco, woods, wool, etc.

The manufactures are related with medium-heavy industry: automobiles and electro domestic devices. The textil industry is also very important.

Argentina produces almost all the petroleum required for its domestic consumption.

Argentine society is relatively a rich developing country. The structure of the National Gross Product (NGP) is similar to those of more developed countries (Services 50%, Manufactures 28%, Agriculture 13%). The income per year and per capita was US $ 1450 in 1975 (the average of developing countries was $480, and $1100 the average for Latin America).

We have, however, faced very hard problems in our development. Argentina suffers from the highest rate of inflation in the world (nearly 150%-200% a year). In addition to that, the wrong economic policies followed during the last years resulted in a negative evolution of the NGP (see Fig.1).

What is even worse, not only the total NGP but the percentage of manufactures in the NGP dropped down from 28% in 1975 to 22% in 1981 (and even a lower value is expected for 1982).

In Fig.2 we can see the structure of the Argentine budget in a typical year (1979).

The amount devoted to Science and Technology was nearly 200 million dollars, without taking into account the financial support due to other sections of the budget (hospitals, universities, armed forces).

Note that the highest fraction of the budget is devoted to "Economic Development" (35%), which means roads and communications. In fact, a large amount of money must be spent on those items in a country so vaste and underpopulated.

We can get an idea of the real effort made on science and technology by analyzing the bureaucratical structure of the financial sources.

We can neglect the private activity in research in a first approach. The structure of the Federal Government (there are also programmes of the member states) is shown in Fig.3.

The SUBCyT (Sub-Secretary for Science and Technology) and the CONICET (National Council for Research in Science and Technology) support programmes in almost every field of science. There are some "level crossings". For example, both the SUBCyT and the CONICET support research work in biomedical sciences. Those activities are performed in laboratories of the hospitals of the Ministry of Health, or in school-hospitals which depend on the Universities.

There are also two institutes for applied research: the INTI for industrial technology, and the INTA for agricultural technology. The Ministry of Defence and each of the three armed forces also have their own institutes for research and development.

The SUBCyT supports many projects in different fields. It has a budget of nearly 6 million US$ per year. The main programmes are on electronics, eradication of endemic diseases and food technology. Only 4% is devoted to research in physics. The same proportion is found in other institutions of the same kind.

3. Research and education

Almost all research in physics is made in official institutions (as CNEA, INTI, CITEFA, etc.) and in public Universities.

The Instituto Balseiro, which is probably the best equipped and staffed school of physics in Argentina, depends on the University of Comahue, and, under a special agreement, also receives funds from the CNEA.

It is very difficult to estimate the total number of professionals working on research in Physics. In 1981 nearly 500 authors presented communications in the National Meeting in Physics. The same number of physicists work in foreign countries. This proportion is one of the most dramatic examples of "brain drain", due to economic reasons and political intolerance.

4. The CNEA. Nuclear Physics in Argentina

The CNEA (National Atomic Energy Commission) is the most seriously planned institution for research in Physics in Argentina. The CNEA depends directly on the President and surveys the basic and applied research in nuclear physics. It also takes care of the medical and industrial use of radioisotopes, the safe handling of radiactive elements, the construction and operation of nuclear electric plants and the extraction of radiactive material.

It also promotes the formation of new researchers through a system of fellowships and by supporting the Instituto Balseiro in Bariloche.

The CNEA installed the first cyclotron in Latin America (1958) and also the first nuclear reactor (RA-1, in 1962). The CNEA built other 4 reactors in Argentina, and is constructing another one in the Republic of Peru, under a special agreement.

At present, a new reactor (RA-6) is being built at the Instituto Balseiro.

The RA-6 is especially designed for educational purposes. It will be used for the formation of nuclear engineers and physicists. It will also produce electric energy for the university campus.

The first commercial nuclear plant in Latin America was constructed by Siemens under CNEA supervision (Atucha, 1972). CNEA also surveys the other two that are being constructed.

One of CNEA's aims is to get the control of the complete cycle of nuclear materials. It surveys the exploration and exploitation of the mines of uranium. A pilot plant for separating deuterium was designed and constructed, and a new plant for mass scale production is now being built near the city of Arroyito.

The activity in basic research is also very important. A big Van-der-Graaf accelerator (TANDAR project) is under construction in Buenos Aires. It will be one of the most important in the world for the study of collision resonances in heavy nuclei.

5. Relation between research and industry

Due to its internal regulations, the CNEA employs a high proportion of national manpower and technology. This attitude stimulates the interaction between basic and applied research and industry.

However, the CNEA is an exceptional case. In general, there is a very slight relation between the laboratory and the industry.

Even in institutions especially created to find a link between research and industry, such as the INTI, the transference of technology is very poor.

On the contrary, the relation between technicians and productors is much more effective as far as agriculture is concerned.

Of course, adequate promotion would favour the participation of the INTI in the industrial development, but the basic difference between the relative efficiencies of the INTI and the INTA is due to the immature structure of the argentine industry.

The industrial recession worsens this misconnection.

On the other hand, and probably due to the tendency of the programmes study, argentine physicists seem to be more inclined to make basic research rather than participate in programmes of applied science.

It is evident that industrialists and scientists should work together in order to reach the desired feedback, but the first step should be done by scientists.

It is necessary to draw the public's attention to the importance that science and research has in their lives.

It is also necessary that scientists understand the problems of their countries in order to be prepared to give them possible and imaginative solutions.

If not, the scientific activity will be considered an exotic and expensive article. The society which supports this activity will not consider it something useful or valuable. Consequently, the society as a whole will not be interested in the defence of this fragile activity against the political or economic turbulences that menace its existence.

Science divulgence and close relation with local industry is not a gracious concession of scientists to "ordinary people". It is the key to the survival of scientific activity, mainly in developing countries, where it does not have the tradition and prestige it has in other societies.

6. Conclusion

I have emphasized the relation between research and industry, that is, the importance of applied science. But what about basic science?

It is clear that without any research in basic science the gap between advanced and developing countries will never disappear. In spite of this, it may sound unrealistic to claim for funds for basic research in countries where hospitals, schools, social promotion and elementary sanitary services are desperately in need.

If we do not think in terms of countries, a scientist is a very particular worker. The final product of his work is unknown. He is essentially working for the whole mankind.

But, again, the poorest societies of mankind might not be in the condition of affording such an expensive activity.

Probably the right answer is not "no research in basic science" or "priority to research in basic science". One should reach some kind of "compromise agreement".

What kind of science do we need (basic, applied. or a mixture, and in which proportion) is a crucial problem, not only for the scientific activity itself but also for the future of our countries. Even though our societies are all different, we have similar problems, and probably similar solutions can be applied.

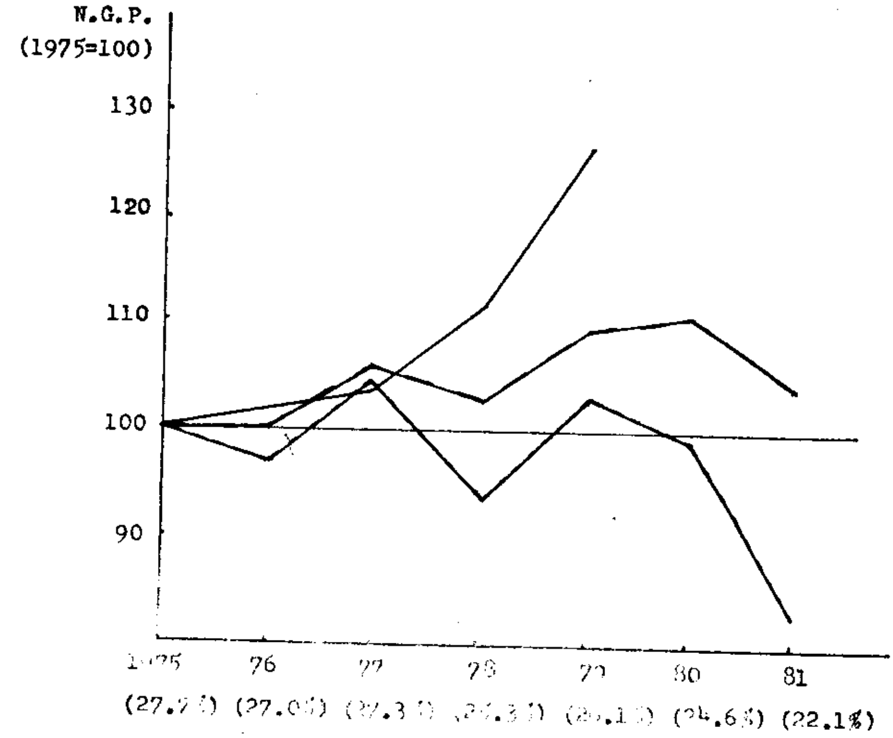
The purpose of the "Physics and Development" programme is to promote the knowledge of the scientific activity in our countries and the discussion of the impact this activity has in our development.

I think that to exchange ideas about what kind of science we need is a good starting point for the discussion.

Acknowledgments

I am very grateful to Professors G.C. Ghirardi and H.R. Dalafi who gave me the opportunity of making this speech. I am very honoured to have given a talk about physics in my country during this programme.

Thanks also to my friend E.D. Sanjurjo who gave me various information about the CNEA.



NATIONAL GROSS PRODUCT (NGP)

Years 1975 - 1981

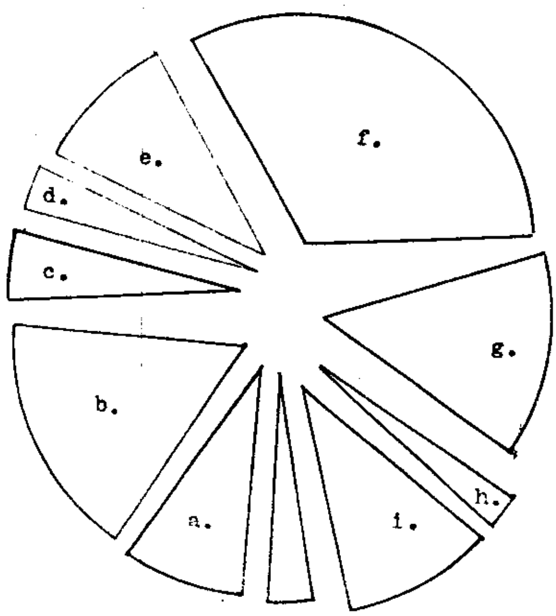
- ——— Latin America and Caribe.
- ——— Argentina (Total)
- ——— Argentina (Indust.)

(23%): $\frac{\text{Industrial G.P.}}{\text{Total G.P.}} \times 100$

In 1975 N.G.P. of the region was 343200 million dollars.

Argentina's N.G.P. was 36749 million dollars.

Fig. 1



<u>ARGENTINE BUDGET</u> (1979)

a. Administration
b. Defense
c. Security
d. Health
e. Education
f. Development
g. Social Assistance
h. <u>Science and Technology</u> (2.2%)
i. Duties

Fig. 2

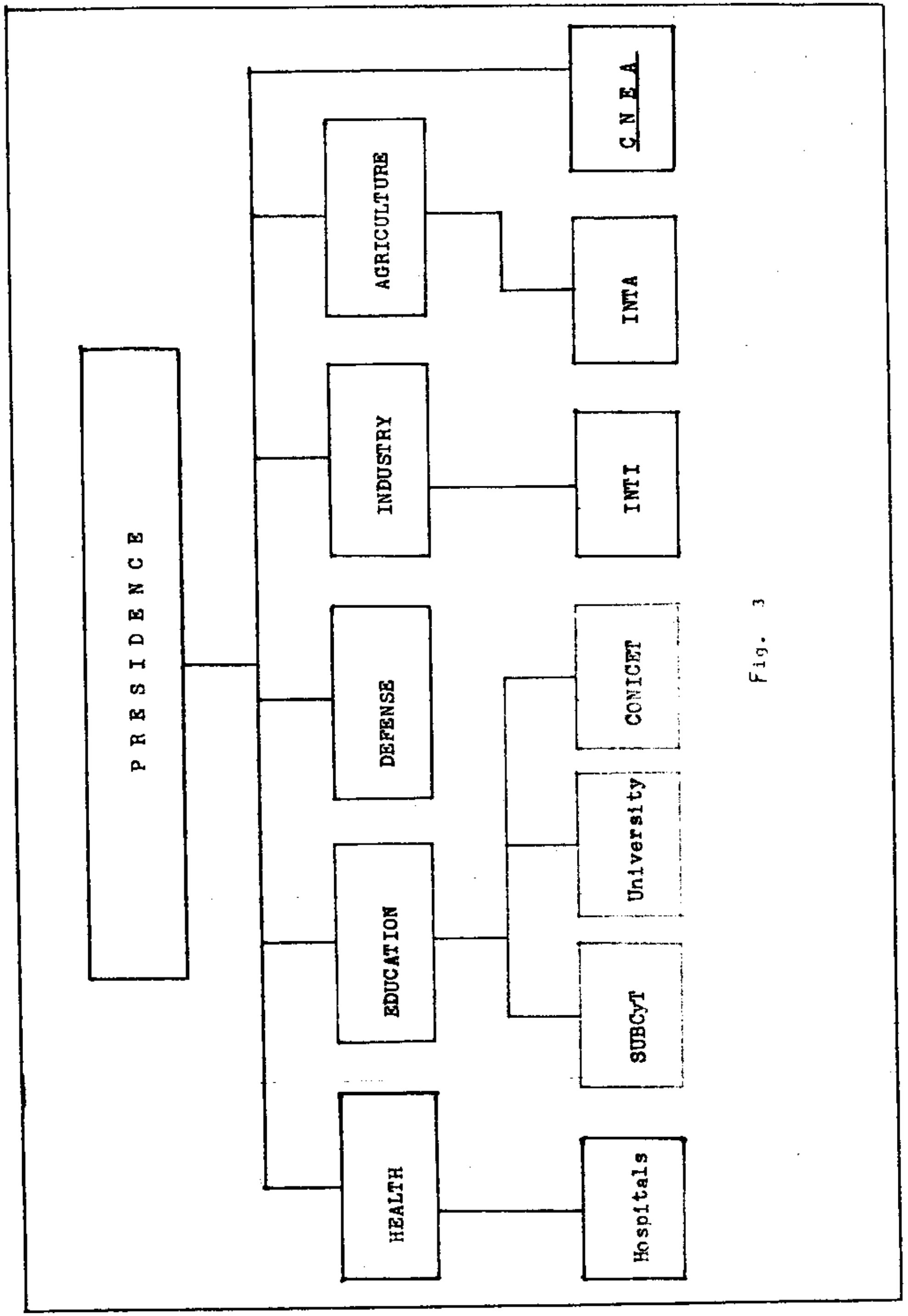


Fig. 3

ON THE DEVELOPMENT OF PHYSICS IN MEXICO

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TABLE OF CONTENTS

I. INTRODUCTION

Being this an invited contribution to the "Physics and Development" programme that the International Centre for Theoretical Physics (ICTP) has recently started, a few comments seem appropriate before advancing to the main topics of this work. First, we would like to thank the organizers of the programme for having given us the opportunity to participate in it.

Our appreciation for this opportunity is two-fold. First, we feel honoured for being able to address the international community to tell them of the past development and present status of Physics in Mexico; this is an immense responsibility that we have tried to fulfill as honestly and impartially as possible. Second, we have always felt a strong concern for our country and our people and it is partly due to this opportunity that such a concern has adopted a more defined shape; the questions have become more specific and, suddenly, we have felt we have a role in the process of looking for alternatives and solutions; and this role seems to be more important than we ever expected.

A thorough scan of research on basic and applied physics in Mexico is not an easy task and, if properly done, would not have taken only a few weeks to complete it. A carefully organized team of people with a well planned strategy would be required to carry out such a mission. Many state universities are actively doing first-class research in basic and/or applied physics. Also, for example, other centers exist througout the country which have been founded by the Natioanl Council on Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACYT) which have not been mentioned in this work. We would like to apologize for such omissions and would like to hope that in the near future a complete listing of institutions where research in physics is done and a list of physicists which includes, amongst other things, their places and areas of work, could become available to the general scientific community of Mexico.

Similarly, it is by no means an easy task at the present time to give a unified view with up-to-date information about economic matters in Mexico. Our country is one of the most damaged by the present deteriorated world economic situation. This is partly due to the fact that since early 1982 an internal economic crisis had already developed in Mexico which gave rise to drastic changes in the government's internal and foreign economic policies. As of today, it is still unclear what the outcome of this situation will be.

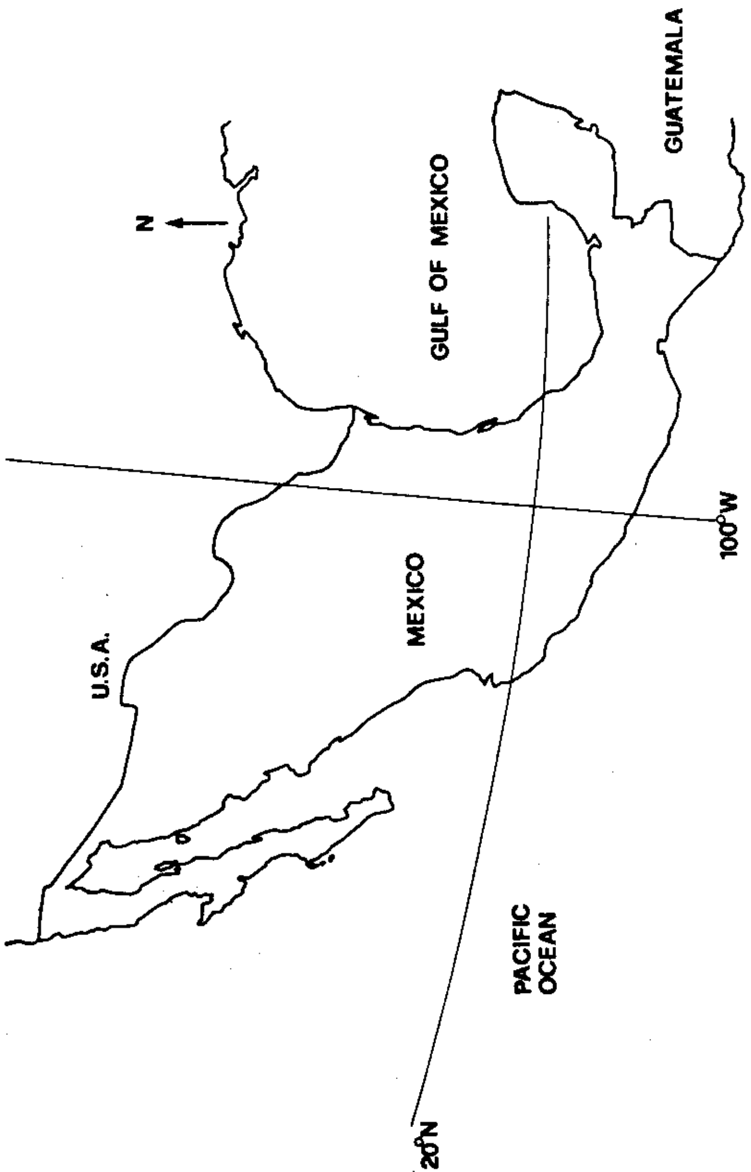
The presentation has been divided into four sections and an appendix. Section I provides an overview of the political and administrative structure of Mexico. Section II presents, in a very succinct manner, what we considered were the highlights of the economic policy of Mexico during the last presidential term (1976-1982) and during the present one (1983-1989). Section III presents in its first part a brief account of benchmarks in the development of physics in Mexico since 1938. In the second part, the present status of Physics in Mexico is reviewed and the perspectives for the future are analyzed. Finally, in Section IV some conclusions are presented.

All the information presented in Sections I and II was obtained from official documents published by the Mexican government which are available to the general public. The ideas which were thought to be more important or relevant to the purpose of this work were extracted and summarized. The economic data shown in the appendix in the form of graphs may not be very representative of the Mexican economy, at present. However, we hope such information can be looked at as a way of defining the "initial conditions" of the problem at hand. All except two of the graphs were obtained from official government publications. The other two were taken from an editorial of the Business Week magazine issue of 28 February 1983.

No institution or person other than the authors is to be held responsible for the ideas, statements, suggestions or conclusions presented here. It has been our objective to respond, as objectively and honestly as possible, to the questions posed in the programme "Physics and development" of the ICTP.

We would like to deeply thank Mr. Hector Cruz Manjarrez for making accesible to us his notes on the history of physics in Mexico, prior to publication, on which most of the first part of Section III is based.

Finally, we would also like to take this opportunity to express profound encouragement to our colleague physicists in every country of the world to more actively partake in this endless endeavour of continually struggling to improve the (social and material) living conditions of the human race.



II. STRUCTURE OF MEXICO

2.1. Geographical and Demographical Information

Mexico is bordered on the north by the U.S.A., on the east by the Gulf of Mexico and the Caribbean Sea, on the southeast by Guatemala and Belize and on the west by the Pacific Ocean. On the North American portion of the continent, Mexico occupies 1,953,128 km^2 of mainland surface area and 5,073 km^2 of surface area on its surrounding islands [1].

Mexico is divided into 31 political states and the Federal District (Distrito Federal). There are 2,375 municipalities, the smallest political division - within the larger political structure of the country.

According to the last population census [2] (1980) the country had 67,383,000 habitants of which there were 33,295,000 men and 34,088,000 women. The total number of the work force with 12 or more years of age was 23,688,000. That is, approximately 35.2% of the population making up the active working force of Mexico.

The State, which has the function of defining and coordinating the development of the country, has the following hierarchical structure based on the political power of each entity:

FEDERAL GOVERNMENT

↓

STATE GOVERNMENT

↓

MUNICIPAL GOVERNMENT

The administrative interaction between the Federal Government and the State and Municipal Governments is carried out via bilateral agreements. That is to say, mutual cooperation and coordination so as to facilitate the implementation of the Programmes for Economic and Social Development in order to accomplish the task leading to the achievement of national goals outlined by the Federal Government as a whole.

The organization of the Federal Government is established in Article 90 of the Political Constitution of the United Mexican States (1917) and fuctioning under prevalent conditions; the different periods of government have - actualized this document in order to obtain a greater degree of clarity and better define the relation between government actions and the population in general.

2.2. Political Organization [3]

In Mexico the people exercize their sovereignity via the powers of the Union which, by the character of the Representative Democratic Federal Republic, is composed of free and sovereign states in reference to everything within their interior regime.

Also, the Supreme Power of the Federation is divided into the following three branches: Legislative, Executive and Judicial. The Legislative Power of Mexico is conferred on the General Congress, formed by the House of Deputies and the House of Senators.

The House of Deputies is composed of 300 representatives (Deputies) of the nation. These 300 members are elected according to the principle of relative majority voting, based on the system of electoral districts (one - representative per district) and up to 100 members elected according to the system of proportional representation based on the system of regional votes for "at-large" members of the state.

The House of Senators is composed of two senators from each state and two from the Federal District, all being elected according to the majority of votes recorded.

The Executive power deposits the exercise of the Supreme Power of the Union on one individual with the title: "President of the United Mexican States". The election of this individual is direct, by effective vote and may not be reelected, the term served having a duration of 6 years.

The Judicial branch is constituted by the Supreme Court of Justice composed of 26 ministers who are appointed directly by the President of the Republic and ratified by the House of Senators.

2.3. Public administration

In the Political Constitution of the United Mexican States, the "Organic Law of Public Federal Administration" is defined, which marks the pace of organization which the Government Sector should acquire in order to manage and regulate the trends of development as well as attain a better organization in its structure.

According to this law, the Public Federal Administration contemplates two aspects: the Central Public Administration and the Combined (Private/Public) Administration.

The Central Public Administration includes:

* The Presidency of the nation
* Secretaries of State
* Administrative departments
* Attorney General's office of the Republic

The combined administration includes:

* Decentralized organisms
* State-partly-owened industries
* National institutions of Credit
* National auxiliary organisms of Credit
* National Insurance and Finance Institutions
* Trusts

All these are hierarchically subordinate to the Secretaries of State and Administrative Departments via the Secretary of the corresponding centralized organism.

In particular, the present administration is continuing, via the Programme of Administrative Reform, with the efforts initiated during the last presidential administration (1976-1982). This programme has as its objectives the reorganization of the activities and structure of the organisms which constitute the Public Sector in order to diminish the duplication of efforts in respect to lines of action proposed by the government. In order to accomplish the study, planning and distribution of the lines of action the Executive branch of the Union relies on the following organisms [4]:

- Secretary of the Government
- Secretary of Foreign affairs
- Secretary of Defense
- Secretary of the Navy
- Secretary of Finances and Credit
- Secretary of Programming and Budget
- Secretary of General Accounting of the Federation
- Secretary of Energy, mines and combined industry
- Secretary of Commerce and Industrial Support
- Secretary of Agriculture and Hydraulic resources
- Secretary of Communications and Transportation
- Secretary of Urban Development and Ecology
- Secretary of Public Education
- Secretary of Health and Welfare

- Secretary of Social Work
- Secretary of the Agrarian Reform
- Secretary of Tourism
- Secretary of Fishing
- Secretary of the Federal District

These amount to a total of 18 Secretaries and a centralized department. This group of government organism performs specific functions that are assigned to them via the "Organic Law of the Federal Public Administration" whose latest version was sent to the General Congress for discussion on the 6^{th} of December of 1982 and was published, once approved, the 29^{th} of the same month.

III. ECONOMIC POLICY

3.1 1976-1982

This period was characterized by the adoption of a "development model" which responded to the growing need to impulse a social, political and fiscal reform through the implementation of Global, Sectorial and State programmes that were designed to define objectives, strategies and policies for development in such a way that an Integral Programme of Development could be established for Mexico. The conception of the National Planning System under the guidance of the government required of the participation of the people as a whole and of the support of various mechanisms: regulatory, coordinating, etc. [5)].

A summary of the actions carried out in this 6-year period was given in the "6^{th} government report" [6)] which the president Jose' Lopez Portillo presented to the country the 1^{th} of September of 1982. In this presentation, the last of his presidential period, the successes and failures of the economic policy were stated. In particular, emphasis was placed on the difficulties encountered in dealing with the economic situation in the country which has prevailed throughout the whole period. The various factors that were said to have directly and strongly affected the national economy were catalogued in two groups: internal and external.

The main external factors were:

* an international economic disorder that "punished" the developing countries
* monetary, commercial and technological aspects that added to the energetic factors and which had to be resolved in global talks at the U.N. in order to avoid dramatic and unpredictable consequences.

The most important internal factors were:

* the difficulty of reconciling the free and open currency exchange policy with national solidarity
* the conception of a "mexicanized" economy as a right of all mexicans
* the concession of the banking institutions to private hands which, though mexican in essence, had shown signs of high speculation and a lack of national solidarity.

These factors were said to have been the cause that in a few years substantial economic resources brought about from savings, oil and public debt fled the country thereby provoking an economic crisis by the end of 1982.

As a consequence of the above considerations the president of Mexico decreed, the 1^{th} of September of 1982:

* the nationalization of all the mexican private banking institutions of the country
* a generalized control of currency exchange and sent to the General Congress a proposal of law that would convert the Bank of Mexico (Banco de Mexico, S.A.) in a decentralized public organism of the Federal Government.

3.2 1983

The present administration initiated its activities the 1^{st} of December of 1982 when Miguel de la Madrid Hurtado was sworn Constitutional President of the United Mexican States. During his first speech the newly elected president defined the political guidelines that he is planning to follow during his six years in office. He particularly emphasized a "Programme of Immediate Economic Reordering" that was defined in order to better defend the country from the economic crisis that it has been submerged in since early 1982.

The central objectives of the programme for immediate reordering of the economy are: to fight inflation, to protect jobs and to recover the basis of a just, efficient and sustained dynamic development. These goals are supposed to be accomplished via the following ten programmed points:

1) a decrease of growth of the government budget
2) the protection of jobs
3) the continuation of construction of selected public works and services
4) a reinforcement of the regulations that will assure discipline, adequate programming, efficiency and honesty in the execution of the authorized public expenses

5) the protection and provision of incentives to production programmes; to import and distribute basic food for the people
6) an increase in public earnings to slow down the boundless growth of the deficit which in turn gives rise to a continuous increase in foreign debt
7) the appropriate channeling of credits for the financing of the highest priority programmes of national development
8) recovery of the currency-exchange process under the supervision of the Federal Government
9) the restructuring of the Public Federal Administration
10) the acting under the principle of rectory of the state and within the content of a combined economy as the Constitution of the Republic establishes.

With this programme the present administration establishes a response to the crisis. The programme is also supplemented by collateral actions which have been defined with the help of public consultation carried out during the electoral campaign of De la Madrid.

The above paragraphs present the political actions and proposed solutions that the present administration has chosen to counteract the effects of the economic crisis. Variations should be expected as the whole world is presently moving into a generalized oil-crisis. Hopefully, good will and common sense will characterize the attitudes and actions of the international community in an effort to avoid a world catastrophe.

IV. PHYSICS IN MEXICO

4.1. Historical overview [7),8)]

If a specific date had to be established as defining the beginning of research in physics, it could be said that physics in Mexico has an age of about 40 years. Its beginning is marked by the foundation of the Institute of Physics (Instituto de Fisica, IFUNAM) within the National Autonomous University of Mexico (Universidad Nacional Autonoma de Mexico, UNAM). It must be stressed, of course, that only intense and continuous efforts of a few people throughout the years prior to 1938 could bring about the foundation of such place. These people who will not be further mentioned explicitly in this work deserve to be called the pioneers of physics in Mexico. Many of them have died, others are still alive.

The years following the creation of IFUNAM were not easy, as can be seen by reading detailed accounts that have been written of those times. Difficult times, which have generated by low budgets for research, reduced space to work and only a handful of investigators and students with enough courage to overcome such problems were the ingredients found in the physics of the 1940's in Mexico.

The original name of the IFUNAM was: Institute of Physical and Mathematical Sciences. This name only lasted a year, however. In 1939 the IFUNAM devoted most of its research programmes to the areas of Cosmic Rays and Soil Mechanics. A happy success was then the inauguration in 1942 of the National Astrophysical Observatory in Tonantzintla, Puebla. In 1943 the Mexican Society of Physical Sciences was founded with Manuel Sandoval Vallarta as its first president but it disappeared in 1950 to give way to the Mexican Society of Physics with Carlos Graef Fernandez as its first president.

In 1954, the IFUNAM counted with four sections. One on experimental nuclear physics led by Fernando Alba Andrade which, by the way, already counted with a 2.2 MeV Van der Graaf accelerator among other things. Another one on theoretical nuclear physics led by Marcos Moshinsky. A third one on X-rays under the direction of Octavio Cano Corona and a last one on gravitation directed by Carlos Graef Fernandez. Shortly afterwards, a laboratory on radio chemistry was created one of whose main objectives was the application of nuclear physics to the dating of archeological samples by using the recently proposed technique of carbon-14.

It is also worthwhile to mention that due to the intense efforts of Marcos Moshinsky, in 1956 the first summer school in physics took place in Mexico with the participation of R.E. Peierls, J.S. Levinger, R.G. Thomas and M. Moshinsky. In 1959, again this event took place with the participation of people such as E.P. Wigner, M. Levy, J. Leite Lopes and M. Moshinsky. The importance of an event like this in Mexico can hardly be overestimated. A few other times the summer school was held in Mexico and then interrupted for some years. Fortunately, it is now back in operation.

In 1958, 12 investigators and 5 assistants constituted the working force of the IFUNAM. Experimental physics in Mexico at the time had on its side some bright and enthusiastic people. Proof of that is the construction of a magnetic spectrograph, only the 3rd of its kind in the world, under the supervision of W. Buechner and Marcos Mazari. Also, a Van der Graaf type accelerator of 0.5 MeV designed to accelerate protons and deuterons in order to produce neutrons via the reaction deuterium-tritum, was finished. Shortly

after that, a Kyropoulos oven was designed and built in order to grow large crystals of NaCl and KCl and a series of three mass spectrometers were also built in those years.

In 1963 an important success took place. The Atomic Energy Commission of the U.S.A. donated a 3 MeV accelerator of positively or negatively charged particles to the IFUNAM. Then, in 1964 the Nuclear Center in Salazor was founded which would eventually house a nuclear reactor TRIGA/MARK III and a 12.5 MeV Van der Graaf accelerator (tandem).

By the year 1970, the IFUNAM counted with 52 investigators that had published over 600 research projects, a 3 MeV dynamitron, a 2 MeV Van der Graaf and, equipment to do mass spectrometry and paramagnetic resonance studies, among other things.

In the last 15 or 20 years the development of physics in Mexico did live its better days and advantage was taken of this bonanza to generate other research centers around the country. For example, the IFUNAM set up two branches. One in Ensenada, a town of 300,000 habitants which is only 110 kms from the U.S.A. border of San Diego, and another one in Cuernavaca, a town that surpasses the half-million habitants and that is located 75 kms south of Mexico City. The main objectives behind the creation of these centers were both to decentralize, which would help in reducing saturation in Mexico City, add to contribute actively to the development of alternate centers for research across the country. In this context, specific mention should be made of another institution, the Center for Investigation and Advanced Studies (Centro de Investigacion y Estudios Avanzados, CINVESTAV) which depends on the Secretary of Public Education. This center, besides being one of the top-most research institutions in the country, has been concerned for a number of years in the development of similar centers for research in places other than Mexico City. As a consequence, a number of centers exist nowadays throughout the country which have been founded with a large number of people having been prepared and trained under the supervision of the researchers from the CINVESTAV at Mexico City. Good quality work in these centers has been a direct result of the active communication maintained between the parent and the newly founded centers. A final example may be given of the development of research centers throughout the country in the last years. The Federal Commission on Electricity (Comision Federal de Electricidad, CFE) a decentralized government organism on which the responsibility of generation of energy for the whole country resides, founded the Institute for Electrical Investigations (Instituto de Investigaciones Electricas, IIE) where research is done on the search for alternate forms of energy production and on the optimization of presently available techniques. The CFE, in conjuction with other nuclear research institutions is also in charge of Mexico's nuclear energy programme. In this respect, two nuclear reactors will soon be put in operation in the state of Veracruz, and plans exist to continue this nuclear programme throughout the country in the next years.

In Mexico City other important research centers in physics and related sciences have also emerged in the last two decades. PEMEX, the government-run oil monopoly, strongly supported the creation of the Mexican Institute for Petroleum (Instituto Mexicano del Petroleo, IMP) as a response to research and technological needs in that area. Other universities in the capital of the country like, for example, the Metropolitan Autonomous University (Universidad Autonoma Metropolitana, UAM) have also succeeded in developing strong groups in certain areas of research, i.e., statistical thermodynamics.

The historical overview of the development of Physics in Mexico, as described in the above paragraphs, is by no means complete. The development of physics at IFUNAM has been emphasized and a few other research centers have been singled out. It is expected, however, that a general realistic impression had been portrayed of the cornerstones in the structure of physics that has been built in Mexico during these last four decades.

4.2. Present status and perspectives.

At present, Mexican physicists are actively working in many areas of physics. At the risk of being unfair to others, it could be said that they have excelled in the fields of Elementary particles, Nuclear physics, Solid State physics, Many-Body theory and Statistical Thermodynamics.

As was mentioned earlier in this section, the most prominent institutions where research in physics is carried out are, probably, the IFUNAM, the CINVESTAV, the UAM and the IMP.

The continued support that the government has given to scientific activities in the last decade or so can hardly be criticized. The oil-boom brought with it money in excess and it could perhaps be said that Mexican physicists even had a chance to overspend it somewhat. Many physics laboratories in Mexico are fully equipped with sophisticated instruments whose acquisition took place without regards to their high cost. Theoreticians and experimentalists have been travelling more or less freely to international meetings in Europe, South America or North America; in some cases their participation being only as observers.

Scholarships were given to just about any student who applied for them to go to the U.S.A. or Europe for a Master's or Ph.D. degree. These have been, indeed, years of bonanza for the physics community in Mexico.

For some of us, the economic crisis that Mexico suffered in early 1982 was a new experience. The process of recession that the world went into and the consequent fall of oil prices in these last months have also been new and threatening experiences. Many countries, including Mexico, are making desperate efforts to adapt and to remain afloat; the final outcome of this situation can hardly be predicted. The panorama has drastically changed from what it was during the 70's for the Mexican scientist.

The effects of the present world economic crisis have already been felt by the scientist in Mexico. Not only has money become scarce; in the lapse of a year or so, the mexican currency (peso) has suffered a devaluation of roughly a factor of 10 with respect to the U.S. dollar. Drastic measures were taken by the Mexican government during 1982, as discussed in Section II. At one point, shortly after the nationalization of the banking institutions, the currency-exchange market was closed. No transactions could be carried out by the general public or the industry with foreign currency. The crisis was at its maximum.

The final overall effect which a double (internal and external) crisis will have on the development of physics in Mexico can, at present, only be guessed. A few implications of this situation, which are fairly obvious, will be discussed in the next paragraphs.

A tightening of the budget for the scientific community is expected. As a result,

2.1. less funds will be available for travelling to international meetings
2.2. less imported equipment will be accessible
2.3. less international meetings will be funded by Mexico
2.4. less scholarships for graduate studies abroad will be available

A discussion of these four points will now follow.

4.2.1. A reduction of direct interaction will probably take place between mexican physicists and their counterparts in other countries. Hence, either more locally supported trips to Mexico from the latter will take place or more frequent resort will have to be made of international programmes for scientific exchange that are frequently found between two given countries or else, via the appropriate scientific departments that international organizations such as the United Nations (UN) or the Organization of American States (OAS), etc., have established in order to foster scientific exchange among their member states. A direct consequence of the above will be the improvement in the quality of research needed to obtain funding for given projects.

4.2.2. Experimental physics in Mexico will be badly hurt. Even though groups of experimentalists exist in the country who actively have tried to develop home-made instruments, whenever feasible, and who have sacrified scientific production (read papers) in an effort to develop the know-how of experimental physics and train well formed experimentalists, many more groups remain who do strongly and critically depend on imported technology and its implications, i.e., replacement ports, maintenance, etc. The impossibility to develop (design and build) a specific sophisticated piece of equipment in a given country must be accepted, however. Realism must permeate this discussion.

Experimental physics will have to turn its eyes to the country. An important action will be that of acting as a catalyst for industry by promoting links with it so as to "suggest" what and, in some cases, how to manufacture to fulfill its needs which are the needs of the country. Years will have to pass before appreciable results can be noticed. This is not a drawback, however; it has to be done sometime or another since by experience obtained from industrialized countries, research and industry are seen to form a symbiosis; one cannot survive without the other. The leaders of the developing nations would do well in remembering this fact.

4.2.3. Although less funds will be available in Mexico for holding scientific gatherings, it may still be possible to attract the international scientific community. The low cost involved in organizing such meetings in Mexico could represent an important factor in making a final decision on the place to hold the subsequent congress or symposium. Care must be exercised however, since the lack of a national mature group in a given field of research is a powerful reason not to hold an international meeting in such a field.

4.2.4. Mexico already counts with first-class scientists in many areas of physics. Hence, students are likely to receive a good formative training in all

but a few areas of specialization. The possibility exists of obtaining a Ph.D. degree in Mexico and then go abroad for, say, a one-year period to work on a pre-determined project. When faced with the other option of obtaining a B.Sc. degree in Mexico and then leaving for 3 to 5 or more years to get a Ph.D. in a foreign country, the former possibility presents interesting advantages. For example, the student would maintain close contact with his home institution while working on an area that, presumably, is of interest to other colleagues in his country. The option of travelling abroad for 3 to 5 or more years is also interesting and could work well provided the institution that awarded the scholarships maintained a tight supervision on the progress of the student and his or her area of work.

The discussion up to now has been made under the tacit assumption that the appropriate government authorities will not profoundly modify their conception of the need of such an élitist activity (research on basic and applied physics) for a country, say, like Mexico. It is of utmost importance that research be not only maintained but increased, at all costs. The catastrophe that would otherwise follow would of course not be felt immediately. It would take a few years before dangerous symptoms were observed. That is when it would be obvious to everybody why research on physics must also be a top - priority - activity in every country in the world.

Only people who are not (or do not want to be) aware of the crucial role that research on physics and other closely related sciences could doubt its benefits. Have they forgotten that, say, light bulbs have not existed forever; that the telephone and the TV were not just hanging from a tree in somebody's backyard; that they would not be able to fly had it not been for the people who, throughout the years, observed and studied the flying of birds and experimented until one of them, finally, figured it out, and another one built the first "flying device"; yes, that their car they normally drive to work everyday was <u>not</u> one of God's creation? It is so extremely sad that those people who lead countries and have the last word on budget matters, are usually the ones that more easily have at their reach the commodities generated by research and technology, are also the ones that more stubbornly impede the provision of funds for research.

There is still one more aspect that deserves special mention in regards to the development of physics in Mexico. To this end, a translation will be presented next of part of a document written in 1950 by Carlos Graef Fernandez to the president of Mexico, Adolfo Ruiz Cortinez.

"...with the present salaries at the National University it is impossible to carry out research. The investigators nowadays have to supplement their income with money they receive for teaching or for doing specific jobs for other institutions; with personnel that integrates its income with small salaries obtained here and there, serious research just cannot be done. The only way to obtain acceptable results in scientific research is by decorously paying the investigators".

The above statements need to be used in Mexico today. The much feared phenomenon of physicists leaving their research institutions or, in the best of cases (and this is debatable), taking up a part-time (sometimes even a full-time) job in a different (not necessarily research) institution, is here already. The detrimental effect that this phenomenon will have on research in not difficult to foresee.

V. CONCLUSIONS

We strongly believe that the attitude of the mexican authorities towards research in physics must be drastically modified so that more support can be given to it. Unless this is done and the importance that the scientific community has for the country is properly assigned, the long-range future for the development of physics in Mexico does not look very promising.

We as physicists must adopt an increasingly conscientious role of our position and possible impact on the society we live in and must participate more actively in the decision making process so as to guarantee the continued support needed to do scientific research.

We are physicists but, first we are members of the society we live in. We are aware of the importance that maintaining research alive has to our country in basic and applied physics. The responsibility rests on us to help people become conscious of such a fact. Our hope is that this work will contribute to accomplish such a formidable task, not only in Mexico, but in many other countries of the world as well.

APPENDIX

The following are selected graphs which will help the reader in understanding the status of the mexican economy up until 1981.

The graphs were obtained from official government publications [9),10)] available to the general public. To the best of the authors' knowledge, data for 1982 have not yet been made available by the government to the general public.

Please note that in some of the figures, a base value has been selected for one year and arbitrarily assigned a value 100.

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FIGURE CAPTIONS

Fig. 1. Total foreign debt at year end and annual increase or decrease in gross domestic product (taken from Business Week Magazine, 28 February 1983).

Fig. 2. Gross National Product (GNP) for 1980 as generated by the different sectors in which the various activities have been subdivided. Note that one (1980) U.S. dollar was equivalent to 12.50 (1980) pesos.

Fig. 3. Total industrial production. In 1980, the contribution of the industrial sector to the total GNP was 37.3%.

Fig. 4. Petroleum industry. In 1980, the contribution of this industry (extraction of raw petroleum and natural gas, oil and by-products, learic petrochemical industry) represented 6.6% of the total GNP.

Fig. 5. Manufacturing industry. This is the most important activity within the industrial sector. In 1980 it represented 23% of the total GNP.

Fig. 6. Consumer's general price index.

Fig. 7. Consumer's partial price index. On the average, about 70% of each family's income goes into: i) food, drinks and tabacco; ii) clothing and shoes; iii) housing.

Fig. 8. Total exports and imports. Exports are FOB (Free on Board) and Imports are CIF (Cost, Insurance, Freight).

Fig. 9. Exports as a function of activity and type of product.

Fig. 10. Exports by product. Some of the main exported products.

Fig. 11. Exports. Raw petroleum.

Fig. 12. Imports as a function of type of product.

Fig. 13. Imports as a functions of product.

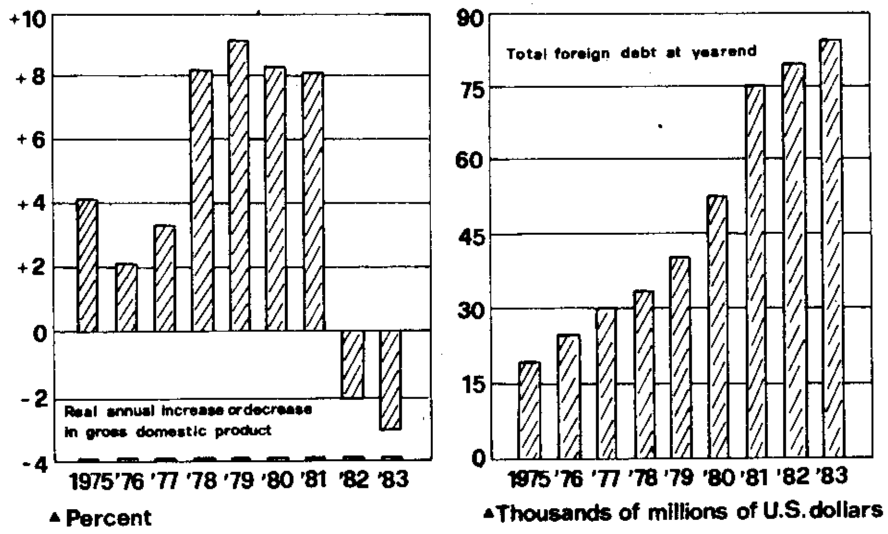
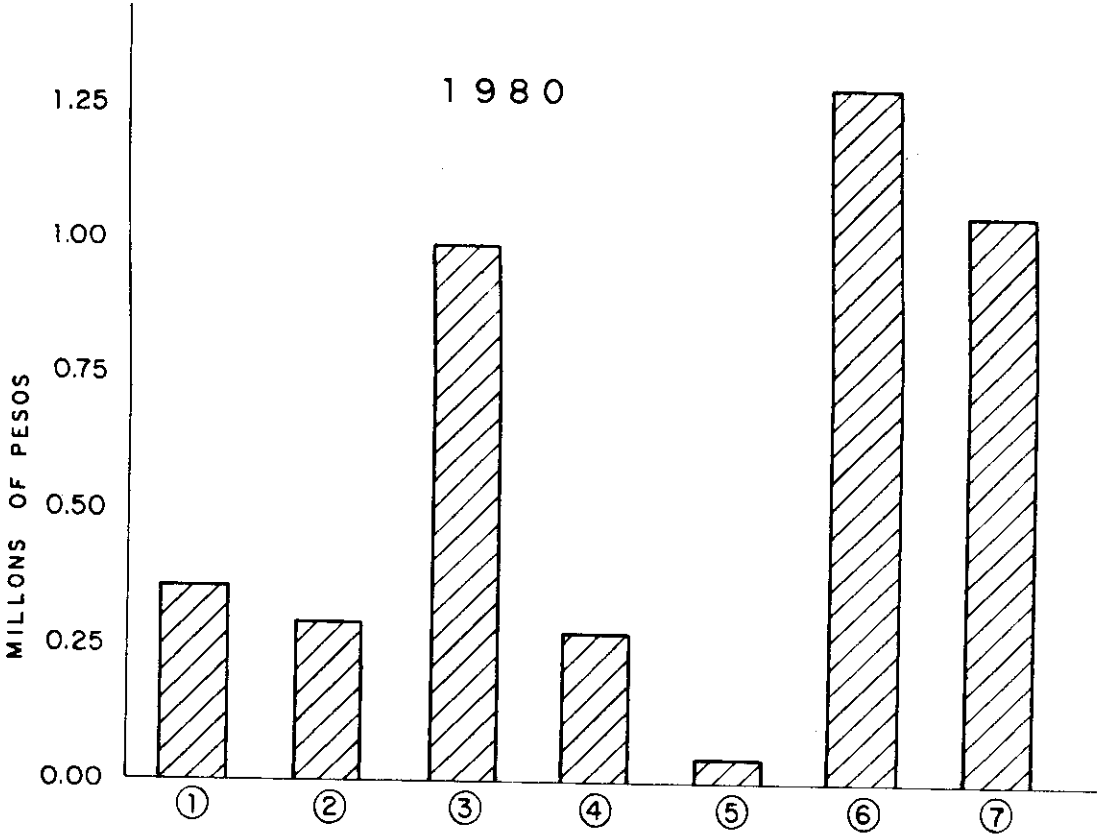


Fig.1



SECTORS:

		%
①	Agricultural.	8.4
②	Mining.	6.8
③	Manufacturing.	23.0
④	Construction.	6.5
⑤	Electricity.	1.0
⑥	Distribution.	29.9
⑦	Rest of services.	24.5

TOTAL GNP : 4,276,490 pesos.

PER CAPITA : 63,466 pesos.

Fig.2

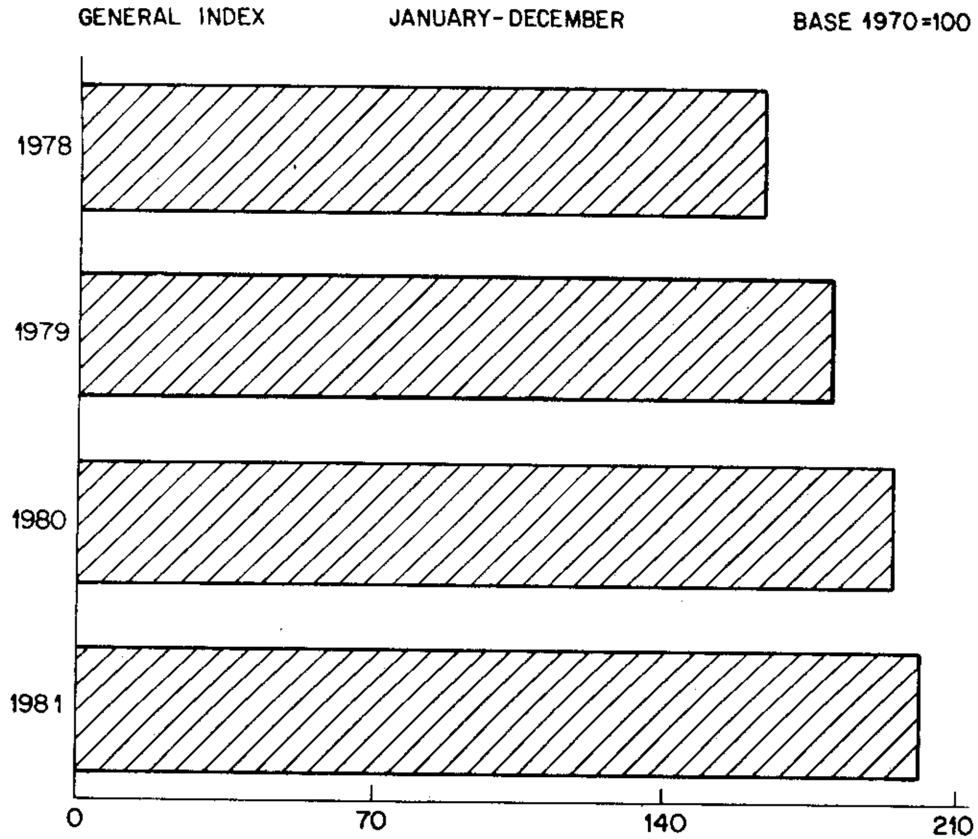


Fig.3

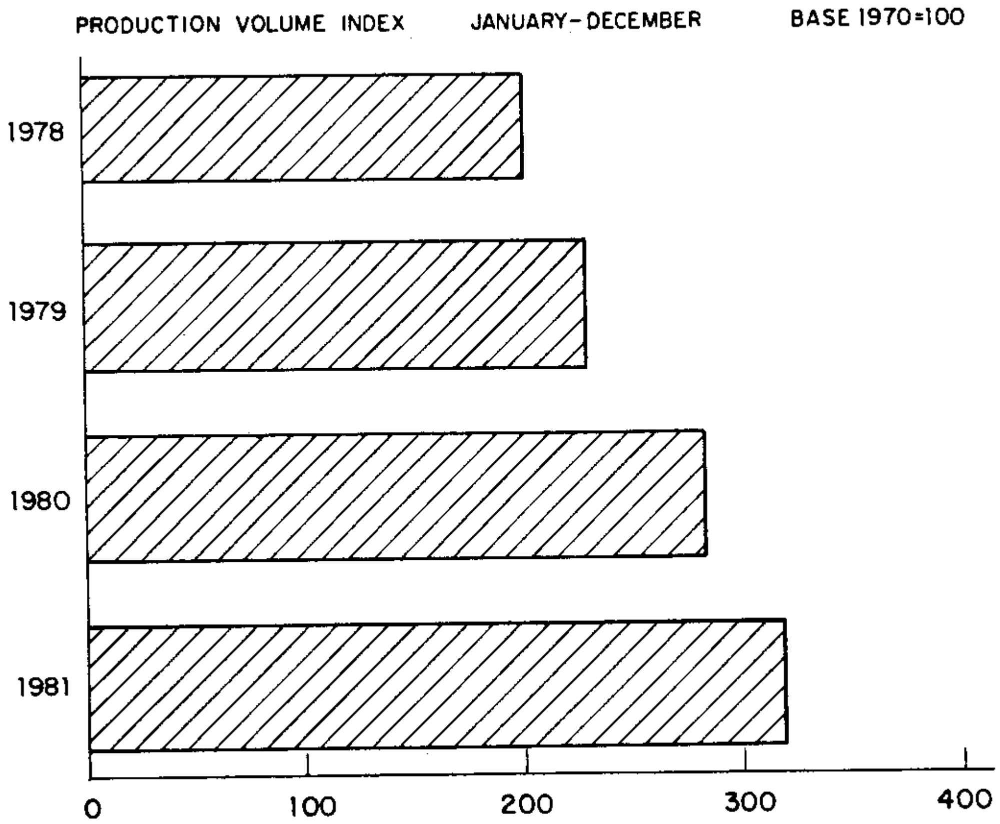

PRODUCTION VOLUME INDEX
JANUARY-DECEMBER
BASE 1970=100
1978
1979
1980
1981
0
100
200
300
400

Fig.4

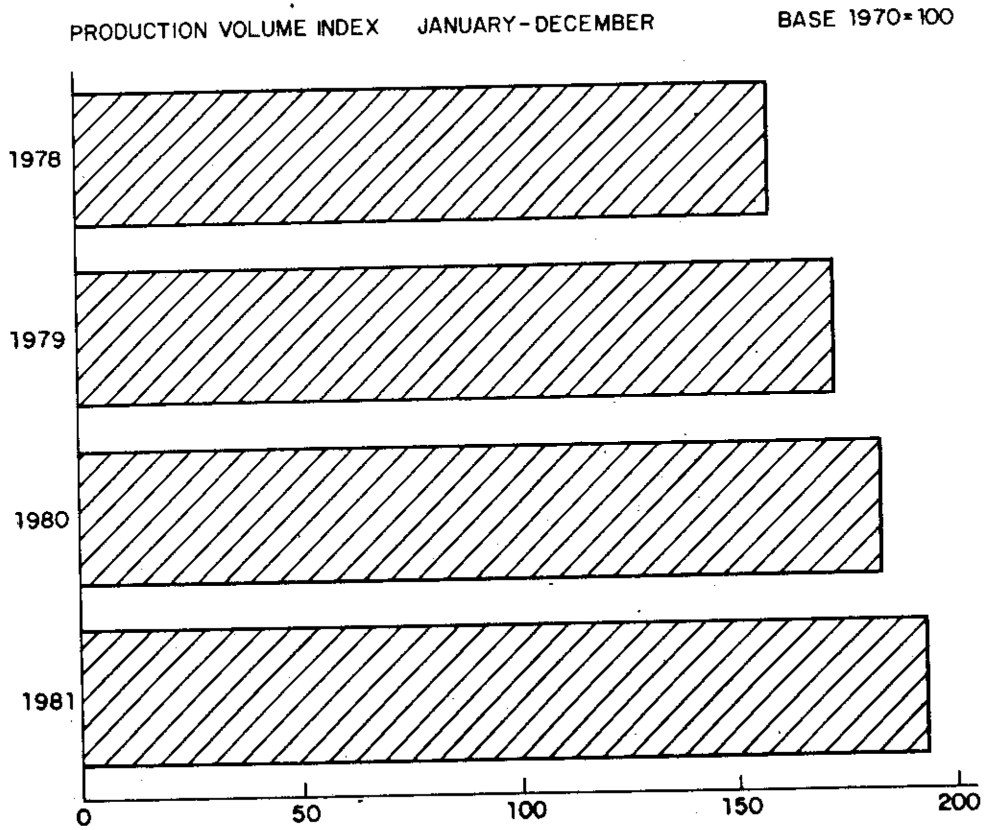

PRODUCTION VOLUME INDEX
JANUARY-DECEMBER
BASE 1970=100
1978
1979
1980
1981
0
50
100
150
200

Fig.5

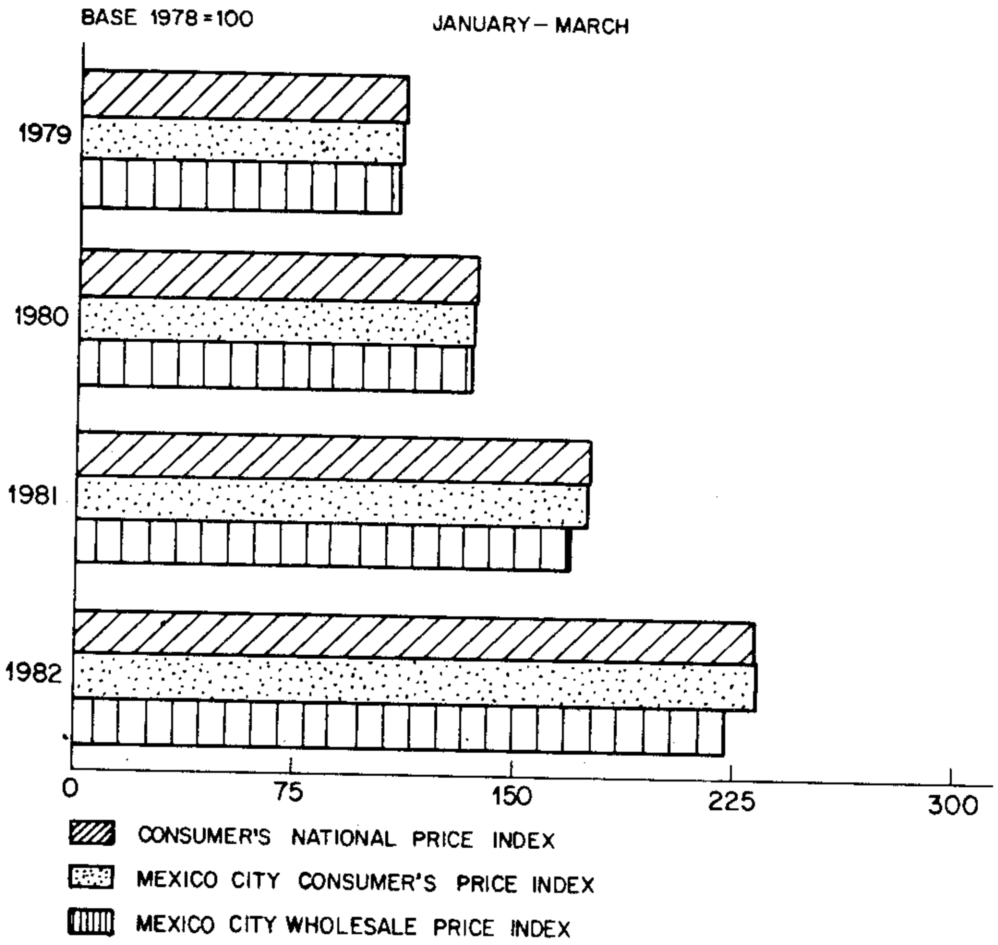

BASE 1978=100
JANUARY – MARCH
1979
1980
1981
1982
0
75
150
225
300
CONSUMER'S NATIONAL PRICE INDEX
MEXICO CITY CONSUMER'S PRICE INDEX
MEXICO CITY WHOLESALE PRICE INDEX

Fig.

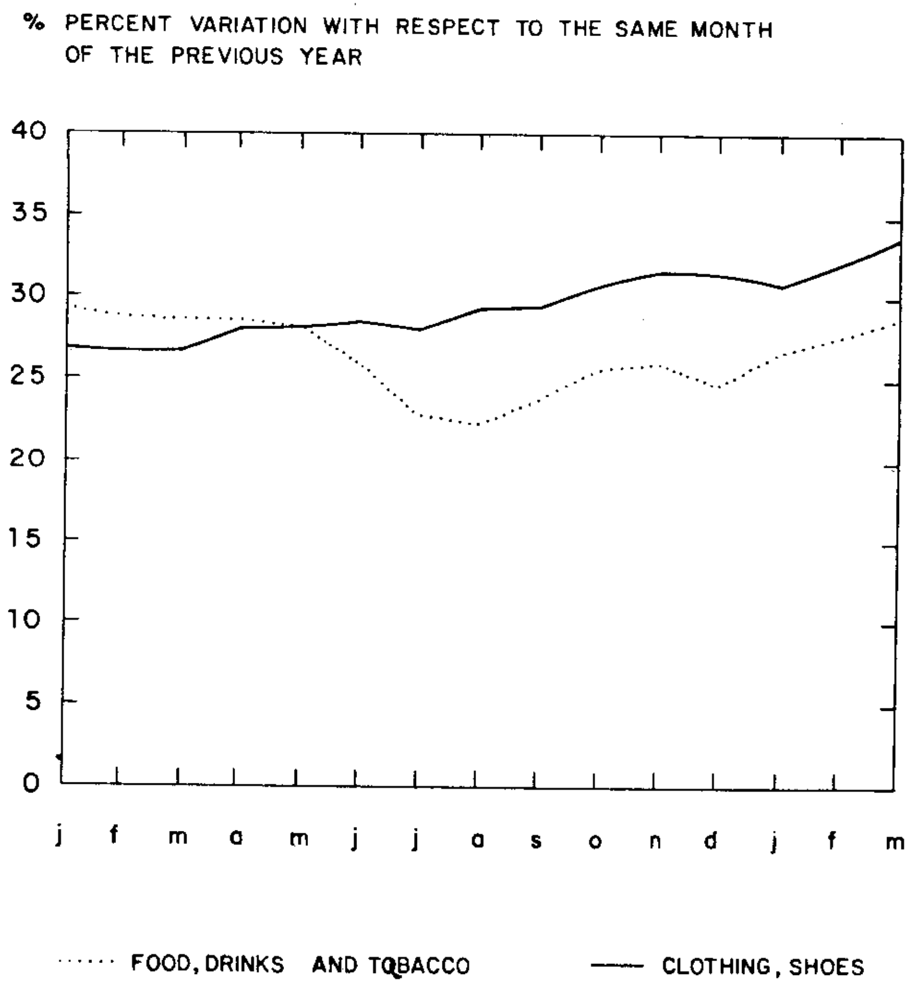

% PERCENT VARIATION WITH RESPECT TO THE SAME MONTH OF THE PREVIOUS YEAR
40
35
30
25
20
15
10
5
0
j f m a m j j a s o n d j f m
FOOD, DRINKS AND TOBACCO
CLOTHING, SHOES

Fig.

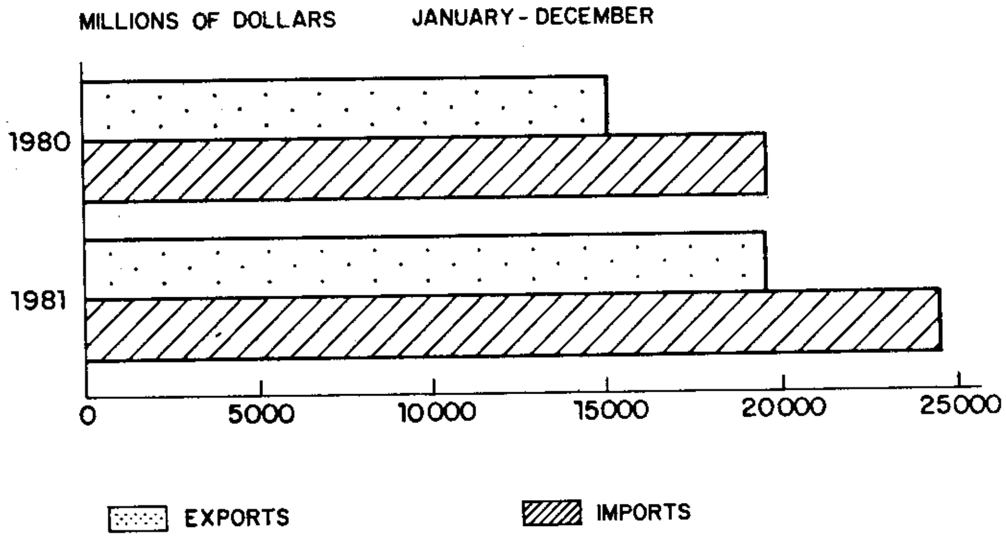

MILLIONS OF DOLLARS
JANUARY - DECEMBER
1980
1981
0
5000
10000
15000
20000
25000
EXPORTS
IMPORTS

Fig.8

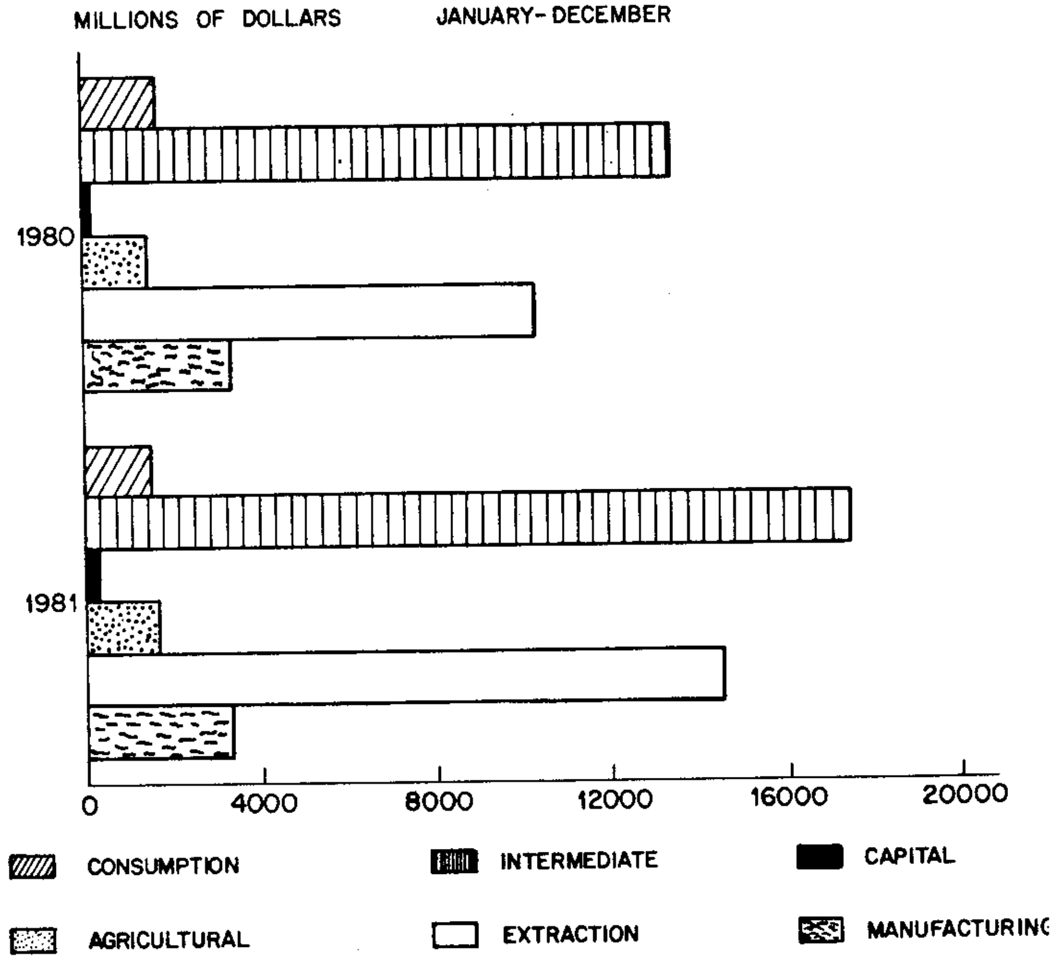

MILLIONS OF DOLLARS
JANUARY- DECEMBER
1980
1981
0
4000
8000
12000
16000
20000
CONSUMPTION
INTERMEDIATE
CAPITAL
AGRICULTURAL
EXTRACTION
MANUFACTURING

Fig.9

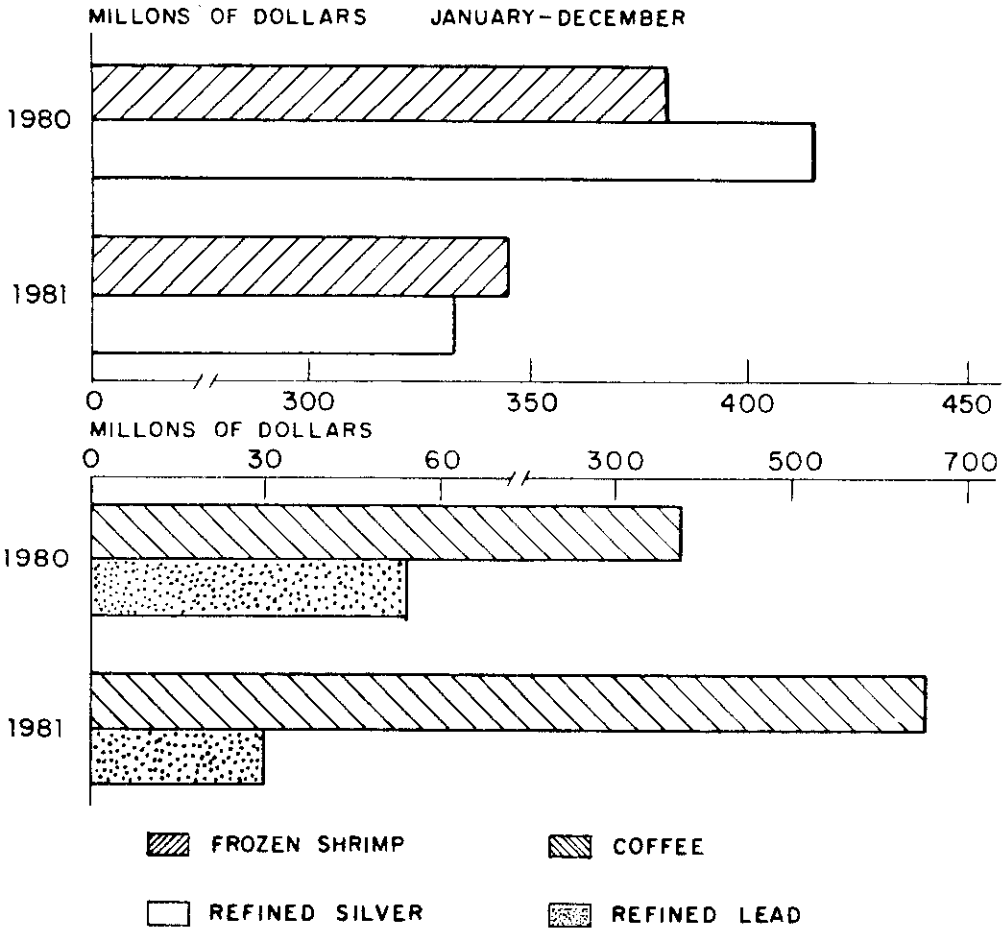

MILLONS OF DOLLARS
JANUARY-DECEMBER
1980
1981
0
300
350
400
450
MILLONS OF DOLLARS
0
30
60
300
500
700
1980
1981
FROZEN SHRIMP
COFFEE
REFINED SILVER
REFINED LEAD

Fig.10

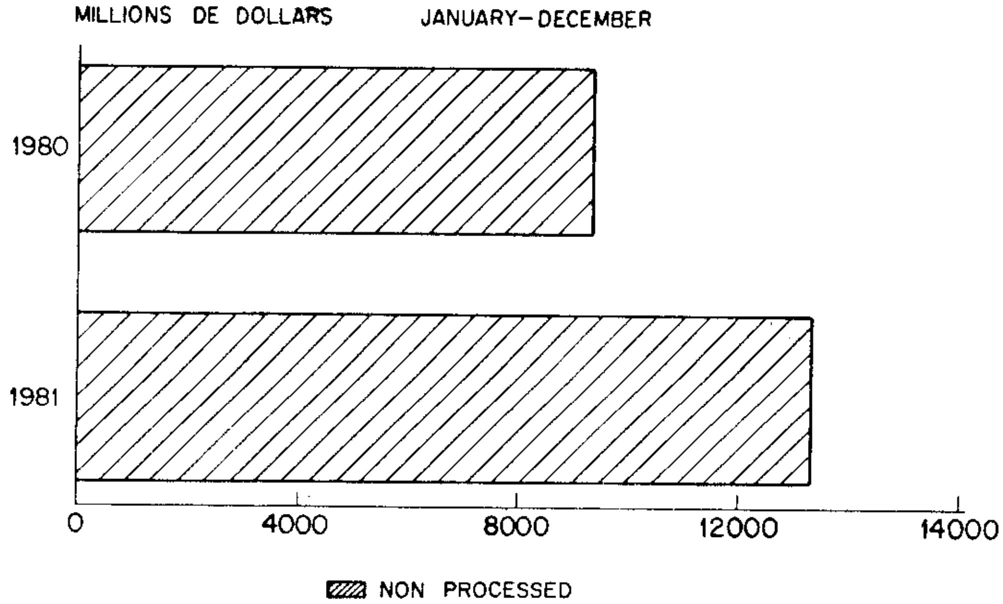

MILLIONS DE DOLLARS
JANUARY-DECEMBER
1980
1981
0
4000
8000
12000
14000
NON PROCESSED

Fig.11

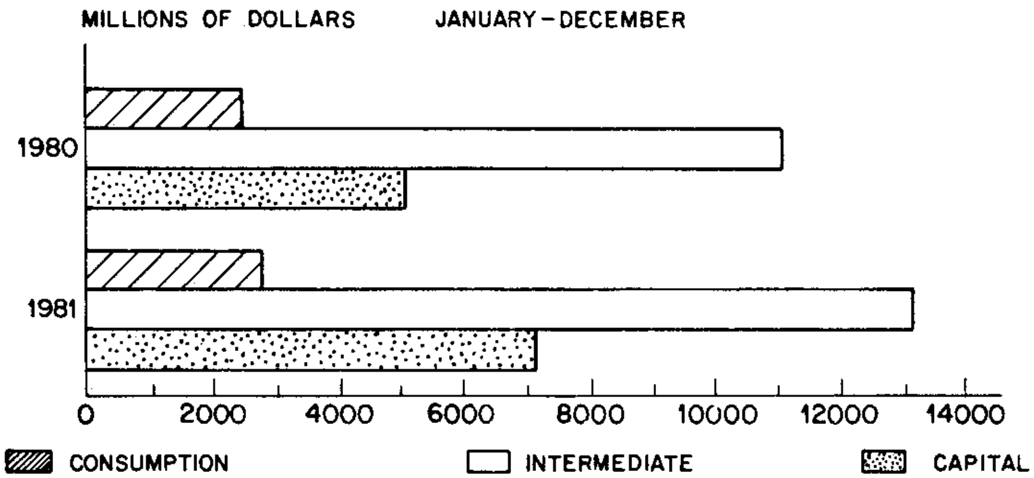

MILLIONS OF DOLLARS
JANUARY - DECEMBER
1980
1981
0
2000
4000
6000
8000
10000
12000
14000
CONSUMPTION
INTERMEDIATE
CAPITAL

Fig.1[illegible]

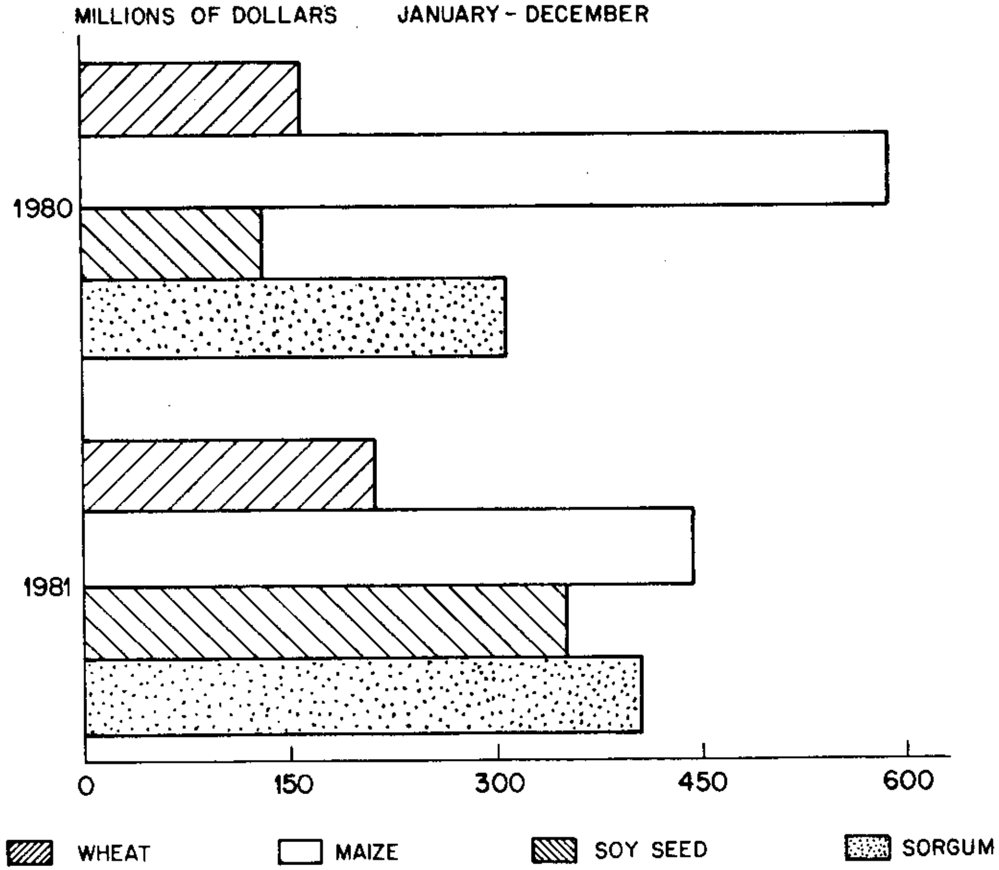

MILLIONS OF DOLLARS
JANUARY - DECEMBER
1980
1981
0
150
300
450
600
WHEAT
MAIZE
SOY SEED
SORGUM

Fig.[illegible]