International Atomic Energy Agency

United Nations Educational, Scientific and Cultural Organization

International Centre for Theoretical Physics

News from ICTP

No. 38/39
September/October 1990

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New Project Leader at ICS - Augusto Forti

Augusto Forti, an Italian geophysicist, became Project Leader of the International Centre for Science and High Technology (ICS) in summer 1990. He is the successor to Giorgio Rosso Cicogna, who guided the ICS project through its two-year preparatory phase, right from its origin as a proposal of Abdus Salam. In November 1990, Professor Forti took up the UN staff member position of Assistant Secretary-General of UNIDO.

Professor Forti has worked in the United Nations system for the last 25 years, most recently as Director of the European Regional Office for Science and Technology of UNESCO at Venice. Previously he was with UNESCO in charge of research in physics, mathematics and problem-oriented research, and responsible among others for liaison with CERN and ICTP.

Under the leadership of Professor Forti, ICS is now consolidating its

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Forti, ICS is now consolidating its activities. New donors have become involved, new collaborations are being set up with various institutes, new diploma courses have been planned, and conferences have been organized — an example being a one-month international course on Research and Innovation Management to be held in June 1991, with Forti's direct involvement.

In 1991 Forti expects to move quickly towards the establishment of fully-fledged ICS institutes, active in pure and applied chemistry, earth, environmental and marine sciences and technologies, and high technology and new materials, evolving with the close co-operation of ICTP. An official inauguration of ICS is planned in early 1991. The new direction the project is taking has been shown great encouragement and interest by the Prime Minister Giulio Andreotti, Gianni De Michelis, Minister for Foreign Affairs, and Antonio Ruberti, Minister for Universities and Scientific and Technological Research.

Professor Augusto Forti

Professor Augusto Forti

Augusto Forti's professional career started in 1956, when he became a professor at the University of Milan after having obtained his PhD there. From his original background in geophysics and geology, Professor Forti moved into science research and later science policy management, working in various capacities directing and advising on research in science and technology and later research and innovation management. In the area of scientific and technological research, Professor Forti has advised numerous scientific academies and national research councils, in at least 15 countries worldwide. Some of the positions currently held include membership of advisory boards or councils, such as the International Relations Commission (MURST); the CNR Institute of Research and Documentation; and the Gulbenkian Institute of Science, Lisbon; and Secretary General of the European Institute for East-West Co-operation.

Professor Forti is a member of the Editorial Board of the Reidl series *Trends in Scientific Research*, editor of the interdisciplinary journal *Prometheus*, and member of the World Academy of Arts and Science. He also writes for several daily newspapers and magazines on research policy, and is author and editor of books in the area of research trends and scientific forecasting.

Léon Van Hove
1924 - 1990

Courtesy of
CERN Courier,
September/October 1990.

Léon Van Hove, eminent Belgian theoretical physicist and Research Director General of CERN from 1976-80, died on 2 September, only eighteen months after a special symposium at CERN marked his 65th birthday and his formal retirement from the Organization to which he had contributed so much.

After training in mathematics he made fundamental contributions to field theory, statistical mechanics and phase transitions, crystal structure, and neutron scattering as a tool to study condensed matter. For this work he was awarded
scattering as a tool to study condensed matter. For this work he was awarded
the US Dannie Heinemann Prize in 1962. He had been working in Utrecht when Viktor Weisskopf invited him in 1961 to lead CERN's Theory Division, succeeding M. Fierz, who was moving to Zurich to take the chair vacant after Pauli's death in 1958.

Van Hove played a major role in establishing the reputation of CERN's Theory Division as a world forum for particle physics ideas. With these theorists working alongside high energy experimenters, he stressed the importance of phenomenology in the quest for new understanding. With his background in statistical physics, Van Hove saw the mass of off-resonance particle production data from bubble chambers, previously discarded, as being ripe for exploitation.

In 1971, Van Hove moved to Munich after Werner Heisenberg retired as Chairman at the Max Planck Institute for Physics and Astrophysics.

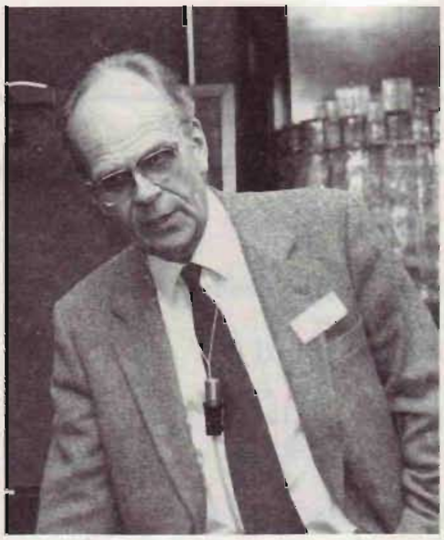
In the early 1970s two CERN Laboratories existed side by side — the original Meyrin (Switzerland) site and the new Prevessin (France) campus of the 400 GeV SPS proton synchrotron. In 1976 these sites were formally amalgamated, with John Adams as Executive Director General and Van Hove as Research Director General.

Under his guidance, the research programme at the SPS flourished, while monumental decisions were taken to go for the proton-antiproton collider, with two big experiments. Van Hove took a special interest in this project, which went on to bring unprecedented honours to CERN and propel the European Laboratory to the forefront of the world research stage. His Research Director General mandate also saw the proposal for the LEP electron-positron collider and initial ideas for its experimental programme. His coordination helped the project receive its rapid consensus approval from the physics community.

Subsequently his vision and experience were widely sought in other European research committees, but with more time available for physics he returned to full-time research with new vigour, making important contributions to current thinking on the behaviour of quarks and gluons under extreme conditions and the interpretation of results from experiments using high
conditions and the interpretation of results from experiments using high
energy ion beams. He also contributed significantly to the analysis of multiple particle production, where he had been invited to report at the recent Singapore meeting, but had to be replaced by his collaborator A. Giovannini.

With the convergence of ideas from particle physics, cosmology and astrophysics, he helped establish the joint CERN/European Southern Observatory (ESO) Symposia on Astronomy, Cosmology and Fundamental Physics as a regular platform. His own powers of synthesis were the source of valuable guidance in this area.

At ease in French, Flemish, German and English, and with a university career spanning several countries, Van Hove was a cultured European. His penetrating insight was frequently evident in major conferences, where his objective comments and conclusions would frequently reorient muddled thinking and provide a real focus for attention.



Prof. Léon Van Hove was at ICTP for the last time in December 1986, when he lectured at the Conference on the 40th anniversary of UNESCO.

Earlier this year, he was invited to give the Nishina Memorial Lecture in Tokyo, where in one of his final public appearances he spoke on 'Particle Physics and Cosmology — New Aspects of an Old Relationship'. Put in a more general context, his concluding remarks mirrored his own disciplined attitude to science — 'a redeeming feature in the midst of so much
attitude to science — 'a redeeming feature in the midst of so much
speculation is the slow but tenacious high quality work being done by observational ... and experimental physicists, while phenomenological theorists carefully evaluate results and confront the various interpretations, the only way to advance in the difficult quest for new ... knowledge of lasting significance'.

(...)

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Professor Léon Van Hove was associated with the ICTP even before its creation. In fact, upon request of the IAEA governing body, with R.E. Marshak (USA) and J. Tiomno (Brazil), he wrote, in 1962, a superb feasibility report which became the charter for the *first ten years of existence of the ICTP. He served on the Scientific Council of the Centre and was the Chairman of one Ad-hoc Committee in 1974 whose recommendations were to re-orient the activities of the Centre.*

Professor Van Hove is remembered at the Centre for his sharp judgement, for the clarity and concreteness of his advice and for his immense sympathy for the mission of the ICTP.

IAEA Service Awards

The Staff Members of the Centre, Deisa Buranello (Supervisor Scientific Programmes Office), Mariuccia Fasanella (Supervisor Reader Services, Library) and Maria Zingarelli (Head of Library), received the 1990 IAEA Service Award on 30 October 1990.

The Award, consisting in a diploma and a gold brooch, was presented to them by Abdus Salam, Director of the ICTP, and Luciano Bertocchi, Deputy Director, in the Main Lecture Hall of the Centre.

News from ICTP presents its most heartfelt congratulations to Deisa, Mariuccia and Maria for their years of hard and succesful work at the ICTP.

Mathematics Education in Pakistan

by Quaiser Mushtaq

Courtesy of The Muslim, *Islamabad, Pakistan.*

Prof. Q. Mushtaq is a faculty member of the Department of Mathematics, Quaid-i-Azam University, Islamabad. Professor Mushtaq, who did his Ph.D in group theory at Oxford University, is now doing research at ICTP. In November, he will be joining MIT where he will spend nine months as a Fulbright Scholar. Amongst the many prizes that Prof. Mushtaq has won, is the Salam Prize for Mathematics in 1987. The prize, awarded annually in a 4-year rotation for physics, chemistry, biology and mathematics, is instituted by Professor Abdus Salam out of the proceeds of his Nobel Prize.

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As also in every other subject, educators in mathematics are faced with significant demographic changes and rising expectations in preparing the kind of work force our country will need in the future. The world of work is now less manual but more mental; less routine but more verbal; and less static but more varied.

Now working smarter is more important than just working harder. We need workers who match this requirement — workers who absorb new ideas, adapt to changes, cope with ambiguity, perceive patterns and solve unconventional problems.

The foundation of science and technology is mathematics. Mathematical literacy forms the basis of technological expertise in the workplace. In tomorrow's world, the best opportunities for jobs and advancement will go to those able to cope confidently and competently with mathematical, scientific and technological issues.

What is needed is a bold and realistic approach to reform mathematics education at all levels. Means must be found for significantly improving student achievement while simultaneously making changes in mathematics education in response to the demands of an increasingly mathematical society.

Our population growth rate is higher than our literacy growth rate. This means that, with the passage of time, we are producing more illiterates than literates.

Even if we consider only those who can afford to seek education, too many of them leave schools without having acquired the necessary mathematical power. Thus, the shortage of qualified mathematics teachers in the country is serious — more serious than in any other area of education. This is the case
serious — more serious than in any other area of education. This is the case
at all levels, from elementary schools to universities.

Mathematics Test Results of Students from Various Countries (Percent correct answers)

Pakistan	15.56
USA	25.30
Switzerland	31.80
France	33.20
Canada	35.80
England	37.80
Australia	37.70
Sweden	37.70
Japan	50.20

From left to right: M. Fasanella, M. Zingarelli, Professor Abdus Salam, Dr. F. Allotey, an old friend of the Centre, and D. Buranello.

If we compare our students with the students of other nations, Pakistani students lag far behind in their level of mathematical accomplishment.

Curricula and instruction in our educational institutions are usually behind the times. They reflect neither the increased demand for higher-order thinking skills, nor the greatly expanded uses of the mathematical sciences, nor what we now know about the best ways for students to learn mathematics.

Generally, it is believed that mathematics is a dry and difficult subject having no practical or aesthetic value, unlike the social science subjects. It is believed that mathematics is intellectually stagnant — overgrown with stale courses that fail to stimulate the interest of today's student.

It is mistakenly thought by many otherwise well-informed people that the mathematics they learned in school is adequate for their children. But mathematics has changed and is still changing. It is significantly more diverse than it was several decades ago. The mathematics commonly used and learned today goes far beyond arithmetic and elementary geometry.

The number of courses has been increased without any agreement on what the added courses should contain or whether enough capable teachers can be found to teach them. There has been an increased reliance on standardised tests. There is very little understanding of what the question papers should contain or what they are capable of testing.

Too much importance is given to the marks one obtains in examinations. marks one obtains in examinations. Few understand that the tests reflect only a small part of curricular objectives. We forget that good marks usually depend upon how faithfully one has been following the prescribed textbooks from the examination point of view. As a result, our students, teachers and parents have become more test-oriented.

The need for mathematically literate manpower compels our institutions to provide more mathematical education to more students than ever before. Accomplishing this will pose significant challenges in developing a core of mathematics which is appropriate for all students.

We need to stimulate able students with the excitement and challenge of mathematics. Our curricula and teaching should be such that they encourage students to explore and verbalize their mathematical ideas. We need to explain to our students the importance of careful reasoning and disciplined understanding.

The teaching of mathematics is shifting from a preoccupation with inculcating routine skills to developing broad-based mathematical power. Broad mathematical power requires that students be able to discern relationships, reason logically, and use a range of mathematical techniques to solve a wide variety of non-routine problems.

Mathematics is a living subject that seeks to understand patterns which permeate both the world around us and the mind within us. Although the language of mathematics is based on rules that must be learned, it is important that student move beyond rules to be able to express things in the language of mathematics. This transformation suggests changes in both curricula and teaching style.

It involves a renewed effort to focus on searching for solutions not just memorizing procedures exploring patterns, not just learning formulae; and formulating conjectures, not just doing exercises. As teaching begins to reflect these emphases, students will have opportunities to study mathematics as an exploratory, dynamic, evolving discipline rather than as a rigid, absolute, closed body of laws to be memorised.

Professionalism in teaching must be strengthened through a concerted national effort. This is an essential element of any effective strategy for reforming any effective strategy for reforming mathematics in Pakistan. It is the teachers upon whom the real burden of reform rests. The task we are setting before them is very demanding. Teachers need to be given the sustained support and working environment that will make it possible for them to carry out their vital mission, that is, teaching and research.

Efforts to bring about lasting change must proceed steadily for many years on many levels simultaneously. Pakistan must move quickly to improve the state of mathematics education, teaching and research if we are not to be left behind in the modern world.

Computer Chemistry at the International Centre for Pure and Applied Chemistry

by N. Rahman, ICC.

The research done with computers in chemistry is taking a major turn for all researchers because of essentially two factors. The computers are becoming accessible to chemists whose background was not previously thought to be oriented towards mathematical or information sciences. Secondly, the cost of computers as well as computing is climbing down dramatically due to rapid development of technology. Both these factors are of major consequence for developing countries. The computers while not replacing a chemistry laboratory, help cut down both the duration and the cost of programmed research in every area of chemistry. Taking note of this situation, ICC intends to fully utilize the central computation facility of ICTP/ICS, those that will be available at the university and the Area di Ricerca. It has started with its own system that consists of a silicon graphics IRIS workstation which communicates with ICC local network and all eventual networks at the other two organisations.

The potential use of computers in chemistry lie in many directions:

1. SYNTHESIS DESIGN — Prediction of possible routes for synthesis for arriving at a desired molecule starting from a commercial or easily prepared molecule. Also routes of degradation of molecule. Also routes of degradation of a molecule with the necessary reagents and experimental conditions. The most well-known program is EROS of Gasteiger of Munich.
2. STRUCTURE ELUCIDATION — With the spectral data (Mass, IR, NMR, NMR-2 etc.) one can obtain a possible set of candidate molecule and with other chemical information (e.g., presence of particular functional groups) it is possible to identify the molecule. CHEMICS by Sasaki (Japan) is typical of such programs.
3. CHEMIOMETRICS — Treatment of experimental data with statistical techniques. Optimization of processes and drug design.
4. DATA BASE — Data bases are used

to manage and catalog a large quantity of data. Protein Data Bank is a prime example. Techniques of artificial intelligence in chemistry useful for structure determination, synthesis design are being widely developed. Another example is the program CHARGE of Gasteigner-Marsili which allows fast computation of physico-chemical properties e.g., atomic charges (sigma, pi), residual electronegativity on atoms, polarity, polarizability etc. which are then used in EROS for synthesis design.

5. MOLECULAR MODELLING – MOLECULAR GRAPHICS — Manipulation and representation in 3D of molecular structure. Graphical representation of electrostatic potential. Docking for pinpointing similarity of structure between two molecules. Assembly of molecular structure for complex molecule using already prepared fragments and subsequent refinements using molecular mechanics.

6. COMPUTATIONAL CHEMISTRY:

a) Molecular mechanics: minimisation of potential energy of molecules. Calculation of geometry. Softwares of these are now widely available.

b) Molecular dynamics: temporal evolution for interaction with solvents or with other molecules. CHARMM of Karplus and AMBER of Kollman.

c) Statistical mechanics and conformational analysis: calculation of thermodynamic quantities and most probable geometries. Analysis of conformational space for a good starting point for minimisation routine. CONGEN of Karplus – software Polygen.
CONGEN of Karplus – software
Polygen.

7. STOCHASTIC AND MONTE CARLO METHODS — Alternative to molecular dynamics. Used in description of drug-receptor interaction and binding of small molecule e.g. oxygen on Fe in haemoglobine.

8. QUANTUM CHEMISTRY — Ab-initio as well semi-empirical methods for small to medium size molecules for charge distribution or geometry of minimum energy. Formation or breaking of chemical bonds and exchange of electrons can be studied only with quantal treatment.

9. ELECTROSTATICS OF PROTEIN — Electric field around proteins solving Poisson-Boltzmann equation.

These and also others are all under consideration by this Centre either directly or through collaboration with laboratories of repute in other parts of Europe such as that in Pisa, in Heidelberg, in Mainz, in Paris etc.

Right now a team of researchers are working there including Dr. H. Moustafa (Egypt) and Dr. R. Urbani (Italy). The system is being set up with the help of Dr. S. Faustoferri of ICS. External collaborators include Dr. B. Schürmann (Germany) and Dr. S. Pongov (Hungary). Prof. S. Miertus (Czechoslovakia) is joining the team for at least six months from October.

Close collaboration with ICGEB is being developed in the field of computer protein chemistry. There is hope that a Master's level diploma course will be soon inaugurated. It appears to be all working to be a good start in a new place and in an exciting new field of research.

Computer chemistry at ICC has been developed under the direction of Prof. N. Rahman who is a professor at the University of Trieste in the Chemistry Department. His interest with computers dates back to 1966 when he, as a research assistant with NASA, was working in atmospheric chemistry using satellite data and modelling with the then largest computer in the world — an IBM mainframe Model 360/91. Since then his research interest has been in other fields such as lasers chemistry and physics as well as time-dependent processes in chemistry. He has always used the relevant computers such as the Cray at Saclay and IBM mainframes at
used the relevant computers such as the
Cray at Saclay and IBM mainframes at
Pisa where he had been an Associate Professor until when he got a chair at the University of Trieste about three and a half years back. It is of some interest to the ICTP that he was one of the first research fellows of ICTP from Pakistan (now Bangladesh) in 1964 i.e., the first year of ICTP working at Piazza Oberdan.

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The International Centre for Pure and Applied Chemistry is one of the components of the International Centre for Science (ICS) of Trieste. The other two components are the International Centre for High Technology and New Materials and the International Centre for Earth Sciences and Environment. Professor Abdus Salam is the President of ICS. Professor Augusto Forti, former Director of the Unesco Regional Office for Science and Technology for Europe (ROSTE) has recently taken up his Project Leader duties, succeeding to counsellor G. Rosso Cicogna who has returned to the Italian Ministry of Foreign Affairs. The United Nations Industrial Development Organization (UNIDO) is the Executive Agency in charge of the Project.

Shudders in the Fabric of Space-Time

This article first appeared in New Scientist *Magazine, London, the weekly review of science and technology.*

Researchers around the world are racing to build a new type of telescope, that will detect gravitational waves from exploding stars, colliding pulsars and cosmic strings.

Throughout the long history of astronomy, researchers have had one main way to understand the Universe: from the message carried by electromagnetic radiation. Although this type of radiation covers a wide range in frequency—from gamma-rays to radio waves—produced by many different sources in the Universe, electromagnetic waves are caused by the same basic physical process, the acceleration of electric charges.

Astronomers could add to this knowledge slightly by studying some
Astronomers could add to this
knowledge slightly by studying some
particles that reach us from space: the "cosmic rays" that are in fact high-speed atomic nuclei, and the highly-penetrating neutrinos from the Sun and from the nearby supernova which exploded in 1987.

But now astronomers are poised to make a breakthrough in observing the cosmos. Within the next few years, four or five new "telescopes" around the world will begin to pick up an entirely new kind of signal from space.

These gravitational waves are shudders in the fabric of space-time itself. The "gravitational wave telescopes" should detect radiation from known sources of cosmic violence, such as nearby supernovae, and from events such as the crashing together of two neutron stars as they spiral in towards one another. More exciting is the chance of making new discoveries about the Universe that are not predicted by our current knowledge and theories.

Gravitational radiation has been around, in the minds of theorists at least, for many decades. Albert Einstein deduced that it must exist, as a natural corollary of his theory of gravity, the general theory of relativity. One simple way to visualise general relativity is to think of space-time (reduced to two dimensions) as a sheet of rubber. A mass, such as a star, placed on the rubber forms a depression in the sheet. If the mass wiggles about, ripples—waves of gravitational radiation—will spread out in the sheet.

This is similar to the way in which charged particles, such as an electron, produce electromagnetic waves. But there is one fundamental difference. A single electron may oscillate without disturbing any other electric charges causing what is called a dipole. The result is electromagnetic "dipole" radiation which is relatively intense.

For a star to produce gravitational radiation, however, then a force must be applied that reacts on another mass. According to Einstein as well as Newton, this reaction must be "equal and opposite". So, the second mass wiggles too, and the gravitational waves from it more or less cancel out those from the first mass. In fact, a detailed calculation shows that the motion of the second mass always wipes out the dipole radiation of the first mass completely.
mass always wipes out the dipole radiation of the first mass completely.
All that is left is a much weaker "quadrupole" radiation.

This means that accelerating masses do not always produce gravitational waves. One example would be a star that explodes as a perfectly symmetrical sphere of gas. In such a system, the quadrupole radiation is cancelled as well. So an absolutely spherical supernova would generate no gravitational waves however violently it exploded. In practice, however, astronomers think that a supernova is rather messier than this and is sure to generate some gravitational radiation.

Astronomers have thought of at least two other kinds of star systems that should produce a detectable amount of gravitational radiation. A neutron star is a very compact object, made almost entirely of neutrons packed cheek to jowl, so it would have an extremely high gravitational field. Many neutron stars spin rapidly, producing pulses of electromagnetic radiation. If a spinning neutron star has a small "mountain" on its surface, it becomes an excellent generator of gravitational waves.

Any two object orbiting each other also generate gravitational waves. In the case of the Sun and the Earth, these waves are too weak to be measured. But if we have two neutron stars very close together, orbiting at very high speed, then they will pump out a significant amount of gravitational radiation. In 1974, radio astronomers found such a pair of neutron stars, swinging around each other in just under eight hours. Over the years, their mutual orbit has gradually shrunk, implying that the system is losing energy—and at exactly the same rate as theory predicts for the energy carried away by gravitational waves. There is little doubt that this pair of neutron stars is generating gravitational radiation, although it has not been detected directly.

Bernard Schutz of the University of Wales in Cardiff pointed out that a pair of stars, such as this one, will eventually spiral together and merge into one body. In its final few seconds, the star system should emit a crescendo of gravitational waves: a loud and characteristic burst of radiation that would sound like a "chirrup" if we hear it.

The gravitational radiation from these it.

The gravitational radiation from these sources can carry a lot of energy. The burst of gravitational waves from two stars coalescing in a galaxy 100 million light years away would arrive at the Earth with a power—if we converted it into terms of optical light—equal to the brightness of the full Moon.

As this ripple in space-time spreads through the Universe, it distorts the shape of any object it passes through. This gives us the means, in theory at least, to detect gravitational waves. It will squeeze a piece of matter in one direction and stretch it in the perpendicular direction. The shape oscillates in time with the frequency of the vibration of the wave as it passes through.

But in reality, the change in size of the object is absolutely minuscule. The gravitational waves from a typical astronomical source would deform a piece of matter by about one part in 10^{20}. So, a lump of matter a metre across would change in size by much less than the diameter of an atomic nucleus.

Undeterred by such predictions, an American physicist, Joe Weber, decided in the 1960s to try to detect these waves. His "lump of matter" was a cylindrical bar, weighing a tonne and made of aluminium. Over the intervening years, many other groups around the world have made more and more sophisticated detectors of this type, usually cooled to a few degrees above absolute zero to improve their sensitivity (see *How to obtain hot results from cold metal*).

Despite all this progress, most physicists believe that bar detectors have reached the limit. One limitation is that they can detect gravitational waves with only a limited range of frequency, near to the tone at which the bar naturally vibrates. More fundamentally, the experimenters are now looking for such tiny movements that they are running into Heisenberg's uncertainty principle,whereby the very act of measuring the changing size of the bar affects the dimensions of the bar by a comparable amount. Along with more recent and pessimistic estimates of the amount of change a gravitational wave would produce, this limitation means that even the most sophisticated bar detectors will be able to detect only the most spectacular—and hence
detectors will be able to detect only the most spectacular—and hence
comparatively rare—outbursts of gravitational waves.

A novel idea for detecting gravitational waves has, however, led to a huge resurgence of interest in gravitational wave astronomy. It promises a more sensitive kind of detector that can pick up much weaker signals, much more often.

After Weber claimed he had detected these waves, Bob Forward, an American scientist then working for Hughes Aircraft, suggested an entirely different kind of device.

Forward argued that a gravitational wave changes the size of a detector by the same tiny fraction, regardless of the detector's size. If we use a detector that is as large as possible, then we would have a change in size that is larger, and so is easier to measure. Forward's scheme was simply to measure the change in distance between two separate masses that are a long distance apart using a laser. In 1973, Forward built the first prototype of this type of detector, with masses 10 metres apart. His experiments led to improvements in laser technology that Hughes incorporated in displays for aircraft cockpits, but Forward could not carry on to build larger detectors for pure astronomical research.

A few years later, Rai Weiss, of the Massachusetts Institute of Technology developed the theory further, while experimenters at Munich in Germany and the University of Glasgow in Scotland began to build prototypes that were 30 to 40 metres long. The leader of the Scottish group, Ron Drever, was later scooped up by Caltech in California to research gravitational waves there. As interest has grown, physicists in France, Italy and Japan have also started to test prototype detectors. These groups are now confident that they can construct full-scale gravitational wave telescopes—several kilometres in size—that are capable of detecting gravitational radiation if our present theories are anywhere near correct.

All the new detectors work in the same simple way: a laser beam is used to measure the distance between two mirrors, fixed to separate masses. When a gravitational wave passes through the detector, the distance between the masses alters, leading to a change in the time it takes for the laser beam to return. The alters, leading to a change in the time it takes for the laser beam to return. The gravitational wave also affects the propagation of the light, but the two effects do not cancel each other out.

In practice, it is easier to measure the difference in the time taken for the light to travel in two different directions, at right angles: the gravitational wave makes one of these distances increase and the other diminish. Even more important, you do not actually have to time the light. You let the beams interfere with one another, and the changing lengths of the arms appears as a change in the interference fringes. This is, in essence, a Michelson interferometer, of the type that undergraduate physics students quickly come to swear at.

By making the arms of the interferometer as long as possible, you can make it more and more sensitive to gravitational waves. But you also run into practical problems. First, the laser beams cannot simply travel through air. Changes in the refractive index of air would easily mask the effect being sought. So the path of light, along both arms, must be enclosed in long metal tubes that are pumped to a very high vacuum.

According to the theory, we need arms that are hundreds of kilometres long if we hope to detect a reasonable number of weak bursts of radiation. Clearly this is not feasible, especially when the beams have to travel in evacuated tubes—even for arms a few kilometres long, these tubes and the powerful vacuum pumps account for most of the cost of the instrument. The answer is to bounce the light back and forth within each tube, up to a hundred times. In some of the prototypes, a narrow laser beam reflects off different parts of the mirrors each time, until it escapes back through a small hole in the mirror at the centre of the device. The groups at Glasgow and Caltech have taken a slightly different approach. Their mirrors form a Fabry-Pérot étalon: the distance between the mirrors is an exact number of wavelengths, so the reflected light sets up a pattern of standing waves.

Either way, the researchers depend on highly reflective mirrors to reflect the laser beam up to a hundred times without it becoming significantly dimmer. These instruments could not without it becoming significantly dimmer. These instruments could not have been built at all without the development of mirrors that absorb less than one ten-thousandth of the light falling on them. These mirrors are a spin-off from the development of laser-ring gyroscopes, used in the navigation systems of military aircraft and cruise missiles, where a beam of light reflected round and round acts as a steady reference against which the electronics can measure the motion of the craft.

Another important component is the laser itself. It must produce light that is always precisely the same wavelength. Drever, at Glasgow and then Caltech, has pioneered ways of controlling the laser so that the wavelength it produces is extremely stable. The laser must also be bright enough for its light to undergo many reflections and still be detectable. The prototype instruments generally use argon lasers, with an output of a few watts, but the groups are now working on much more powerful neodymium-yttrium-garnet lasers, which should produce about 100 watts.

The research groups that are about to build full-scale gravitational wave detectors are not so much in competition as in a loose collaboration. Although there will be a certain kudos attached to the first definite detection of gravitational waves, it is an honour that no group expects to have to itself. The history of the subject has taught the experimenters that other scientists will be sceptical of a claimed detection unless it is backed up by results from a completely independent instrument.

The other advantage of working together is that a single gravitational wave detector can tell astronomers very little about the direction from which the radiation has come. As the wave sweeps through the Earth, at the speed of light, it will, however, pass different detectors at different times. If the experimenters compare notes of the exact times when the waves are passed through each detector, they can calculate the direction in which it was travelling.

The more spread out the detectors are, the more accurately the researchers can determine the direction of the source of the gravitational waves.. With a set of detectors spanning the Earth, they should be able to pin down the direction of the source to within a few arcminutes (about a quarter the apparent size of the Moon) source to within a few arcminutes (about a quarter the apparent size of the Moon). For sources beyond our own Galaxy, this should be good enough for the astronomers to identify the galaxy that produced the radiation. This accuracy will also allow astronomers to check if there was a burst of electromagnetic energy at the same time— as would be the case with a supernova.

For direction-finding, the best way of locating the source of the radiation is to use four detectors at the corners of a tetrahedron. More by luck than anything else, the research groups interested in building the detectors are spread out in roughly that way: on the east and west coasts of the US, in Europe and in Australia.

The American groups at Caltech and MIT have formed a consortium, the Laser Interferometer Gravitational Wave Observatory, to construct a pair of identical instruments, one on each coast. The western detector may be at the Edwards Air Force Base in California (where the space shuttle lands) and the eastern one in Maine or Louisiana. Each will have arms that are four kilometres long, with their light paths side by side, so that several different gravitational wave detectors can work simultaneously. These could be of slightly different design, or respond to different frequencies. Both the National Science Foundation and President Bush have backed the proposal, worth $192 million (about £118 million) and it is awaiting approval from Congress later this year.

All being well, Europe will also have two gravitational wave detectors, though these are being built by separate teams. A French-Italian consortium is planning a gravitational wave detector with arms three kilometres long, that will be sited near Pisa. Researchers at the University of Glasgow and the Max Planck Institute for Quantum Optics at Garching are also designing a detector with three-kilometre arms. Jim Hough, at Glasgow, has already located a suitably flat and accessible piece of land in Tweedsmuir Forest, near St Andrews, and the instrument has been granted planning permission. But the location will almost certainly be decided by the relative financial contributions from the two countries. In July, the British Science and Engineering Research Council allocated £5.5 million to the Science and Engineering Research Council allocated £5.5 million to the telescope. Researchers expect that the Germans will soon commit themselves to providing the rest of the £30 million required. The contributions will be split between the Max-Planck Institute, the Federal Ministry for Research and Technology (BMFT) and the local government of Lower Saxony.

All these detectors are in the northern hemisphere, and at much the same latitude. In order to tell accurately how far north or south a source lies in the sky, astronomers must also use a detector in the southern hemisphere. To complete the "tetrahedron" at its southern corner Australian and Japanese scientists are planning to build an instrument near Perth. The Japanese research group at ISAS, near Tokyo, has already built a prototype, with arms 10 metres long. They will work with the Perth group that already operates a cooled bar detector and with optical experts from the Australian National University. Although the Australian federal government has yet to approve the project, the state government of Western Australia has already promised A$5 million (about £2 million) of support, in the form of land, roads and electricity.

All the groups are confident that their experience with the small prototypes has ironed out all the major problems. It will take about three years to build a full-scale instrument, and another two or more years to test it out and get it running smoothly.

By the late 1990s, then, astronomers should have ploughed well into the new field of gravitational wave astronomy.

Every year, the detectors should be picking up several bursts of radiation from supernovae in other galaxies, out to a distance of perhaps 100 million light years. There should be dozens of "chirrups" per year from neutron stars that are running together and coalescing in galaxies up to 300 million light years from us. Bernard Schutz has calculated that by measuring the gravitational waves alone we can work out how far it is to such a coalescing star pair: by identifying the parent galaxy and measuring its speed away from us, astronomers will be able to calculate the rate at which the Universe is expanding (the Hubble constant). This will help astronomers locate more precisely more (the Hubble constant). This will help astronomers locate more precisely more remote galaxies and quasars, and provide new evidence on the age of the Universe.

Still in the realm of cosmology, some theorists have predicted that the big bang produced "cosmic strings"—discontinuities in space-time that act like long, thin strings with a strong gravitational pull. Loops of cosmic string could have acted as seeds around which the galaxies formed. If this were the case, the loops of string would get smaller and eventually disappear, producing a burst of gravitational waves in the process. The new detectors may well find this radiation forming a background to their other measurements.

And, at the most basic level, detecting gravitational waves at all is an important test of general relativity. The experimenters will also be able to test if the polarisation of the wave matches up with the predictions of relativity.

But the most exciting prospect is that a new window on the Universe opens up the chance of unexpected discoveries. Radio astronomers stumbled upon quasars, and X-ray astronomers were unprepared for black holes. Who knows what objects may exist in the Universe that choose to reveal themselves only by their output of gravitational radiation.

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How to obtain hot results from cold metal

The heart of the first gravitational wave telescope was a bar of aluminium, 1.5 metres long. A passing gravitational wave would alter its length by less than the diameter of atomic nucleus. Its designer, Joe Weber of the University of Maryland, fitted very sensitive electronic transducers to the ends of the bar, to record changes in its length. He knew that the transducers would show that the bar was continuously shrinking and expanding by small amounts, just because of the randomly changing vibrations of the atoms. Normally, such vibrations would have swamped any disturbance from a gravitational wave.

This was where the choice of aluminium came in. If you hit a suitably supported bar of aluminium, it will keep on ringing for a very long time, perhaps for hours. Each random vibration of an atom acts like a minute hammer blow, and sets the bar ringing, vibration of an atom acts like a minute hammer blow, and sets the bar ringing, so the changes in length from these vibrations is averaged out over a period of hours. A gravitational wave produces a much smaller signal in the detector, but because it changes the length of the bar in only a fraction of a second this signal will stand out from the much larger but very gradual changes caused by the vibrating atoms.

In 1969, Weber confidently announced the discovery of gravitational radiation: his bar was detecting one gravitational wave burst per year. This result was astonishing. The strength of the signal Weber claimed to have measured meant that our Galaxy was destroying a star like the Sun every year. At that rate, one-tenth of its matter would have been destroyed since the Galaxy was born.

This extraordinary claim spurred other scientists to build similar detectors, to see if they could duplicate Weber's result. In the end, no one could. To this day, it is not clear what Weber was detecting—most probably some kind of noise in the apparatus. But the episode had important consequences. It opened researchers' eyes to the fact that a gravitational wave detector could be built. But they would need simultaneous detections from at least two different detectors before other scientists would be convinced of the discovery of a burst of gravitational waves. Weber's work also prompted theorists to take a closer look at the generation of gravitational waves. They concluded that the waves would be even weaker than first believed.

Clearly, the experimenters needed to improve the sensitivity of their detectors.

Since the main problem is noise from the natural vibration of the atoms, it helps to cool the bar down to just a few degrees above absolute zero. Several groups around the world have now built such "cooled bar" detectors. There is an Italian detector at the European particle physics laboratory near Geneva (CERN) and there are detectors in Japan and in Louisiana in the US. Physicists at Stanford in California have been operating the largest such "telescope", an aluminium bar weighing five tonnes: the more massive the bar, the better it responds to both gravity and gravitational waves. This instrument gravitational waves. This instrument was damaged in the Californian earthquake last year, focusing the group's work on a new and even more sensitive aluminium bar detector.

At the University of Western Australia in Perth, David Blair has gone for quality rather than quantity. Instead of using larger amounts of aluminium he has investigated which materials will "ring" for longest when struck. The best is sapphire, but it would be difficult to obtain a lump of pure sapphire weighing a tonne or more. So Blair has opted for a 1.5 tonne bar of niobium, the metal that will ring for longest. Because the metal is not consumed in the experiment, the bar worth A$500 000 (about £200 000) is owned by the university's investments board. Blair is still sorting out problems in preventing vibrations from reaching the bar from the outside world; later this year he expects to reach the same sensitivity as the biggest aluminium bars.

Japanese researchers have taken a different tack. Their detectors are tuned to the frequencies of some nearby rotating neutron stars that are powerful emitters of electromagnetic radiation, such as the neutron star in the centre of the Crab nebula. By looking for just one frequency that is known in advance, they can filter out most of the noise.

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The supernova and the warm bar

At the moment, the most sensitive detectors are the big cooled bars: they are about 10 times better than the prototype laser interferometers. The cooled bars should certainly be able to detect cataclysmic events in our Galaxy or our closest neighbours, although such events are rare.

By a strange irony, one such event did occur recently: supernova 1987A in the Large Magellanic cloud. At the time of the outburst, however, none of the cooled bar detectors was running. They operate for only a few months a year, with the rest of the time being spent in improvements, or simply in cooling down and warming up the tonnes of metal.

But the supernova saga has a strange footnote. There are a few bar detectors that are not cooled at all. These are much less sensitive than the cooled bars, and few scientists expect them to detect anything astronomical. But two "room anything astronomical. But two "room temperature bars", in Maryland and Rome, were operating when the supernova exploded, and seemed to have registered a signal.

If this signal was real, the wave was carrying the energy equivalent of thousands of Suns, while the star that exploded was only as heavy as 20 Suns. The Rome group think their "signal" was probably just noise that happened to occur at the right time. Weber, in Maryland, believes that it was a real signal, and that the theory of the detection of gravitational waves is wrong: he claims that bar detectors are thousands of times more sensitive than any one had previously thought.

The Need for Mathematics

by Quaiser Mushtaq

Courtesy of The Muslim, *Islamabad, Pakistan.*

The advancement and perfection
of mathematics
are intimately connected
with the prosperity of the state.

Napoleon I

The world is going through a period of major political, economic, military and technological changes. These changes present unique challenges and opportunities. Countries are becoming superpowers on the basis of their economies alone.

The world's geopolitical polarity is shifting. Old alliances are moderating on both the Soviet and US sides, new forces are emerging, overpowering military force is appearing less useful than before, and communist countries are clearly concerned about what their poor economic condition portends for their long-term power and status.

Like many other Third World countries, Pakistan is coping with complex fiscal and technical efficiency problems which challenge our work and market ethics and our competitive abilities.

The challenges that we face today are daunting. We need, today, to deal with vast quantities of data in an efficient manner. We need to distinguish manner. We need to distinguish important objectives from the unimportant ones, supporting decision making in time critical environments, converting complex situations and problems into simplified, understandable ideas and improving communications and information management. All this involves mathematics.

These changes cannot be understood nor these challenges met by relying solely on the theories of the past. Rather, we must have fresh insights, new ideas, and a deeper understanding of the way the world works. These are tasks uniquely suited for the mathematically trained mind. Yet our nation lacks a sufficient number of such minds.

We have 22 universities in Pakistan, but the total number of mathematicians in these universities in only 124. There are about 55 mathematicians in Pakistan with Ph.D degrees. Since 1947, only 7 Ph.D's in mathematics have been produced here.

Great Britain, for instance, which has half the population of Pakistan, boasts about 2,500 high-class Ph.D's in mathematics in its universities alone. A tiny country like Singapore, whose population is 2.6 million and which has only one university, has approximately 60 mathematicians.

The condition in Pakistan is thus practically hopeless. All mathematics departments in the country are understaffed. Pakistan is devoid of mathematically skilled manpower everywhere — in DESTO, PAEC, PINSTECH, KRL, HMC, the Pakistan armed forces, etc.

On the other hand, the world has become more mathematical in recent years, and this change can only accelerate. Modern technology and science demand a comfortable command of discrete mathematics, statistics and mathematical modelling — and these are just the entry-level requirements.

When we cannot find mathematically literate workers, when the government can no longer recruit the mathematically skilled, and when we must finally rely on the scientific insights and advances of other nations, then we will have entered a sad period of technological stagnation and decline. This will result in more reliance upon foreign aid and more dependence upon the technological and
reliance upon foreign aid and more
dependence upon the technological and
scientific knowledge of others. We will spend huge amounts of foreign exchange buying necessary and important equipment and expertise.

There is also a great need to move beyond the artificial divisions of mathematics: pure versus applied; defence versus civilian; industrial versus academic; research versus teaching. We must realise that what is good for mathematics in its broadest sense benefits every user, no matter how narrowly focused the application may be.

There are plenty of reasons for promoting mathematics. Let us consider a few examples of the broad application of mathematics. In the 1800s, mathematicians expended a lot of energy on the wave equation — a partial differential equation arising from the physical properties of waves in a string or in fluid.

Despite the physical origin, the problem was one of pure mathematics: nobody could think of a practical use for waves. In 1864, Maxwell laid down a number of equations to describe electrical phenomena. A simple manipulation of these equations produces the wave equations. This led Maxwell to predict the existence of electrical waves.

In 1888 Hertz confirmed Maxwell's predictions experimentally, detecting radio waves in the laboratory. In 1896, Marconi made the first radio transmission.

This sequence of events is typical of the way in which pure mathematics becomes useful. The same sequence of events occurred in the development of atomic power; or in matrix theory of Cayley (used in engineering and economics); or in integral equations, which took about 30 years to develop, from the point where Courant and Hilbert developed them into a useful mathematical tool to the point where they became useful in quantum theory.

Nobody could have realised at the time of Galois that group theory would turn out to be needed later in almost every branch of science. This means that all mathematics, however unimportant it may seem now, should be encouraged on the off chance that it will be needed later.

Overall, mathematics is becoming even more essential to our defence, to our industrial competitiveness and to our
even more essential to our defence, to
our industrial competitiveness and to our
nation's academic research. The role of mathematics in the future of Pakistan's economy and government will be central, crucial and inescapable. Mathematics will be one of the skills that separates service careers from those requiring imagination, creativity and originality.

Supporting and improving mathematics can no longer be merely a slogan, goal or platitude. It must now become an essential objective of any industry, scientific organization, government, or academic institution that expects to remain competitive in the future.

We simply must ensure that adequate support for mathematics research is an accepted norm, that our standards for pre-college education are equal to our capabilities and needs, and that the standard of mathematics and teaching of mathematics at these levels is improved. The decline must stop now, and we each have a role to play.

In the past, our government and the private sector have taken a limited and narrow approach to mathematics. If the work in question is not 'mission oriented', if it does not increase profits, if it does not have an obvious application, then it is not worthy of support.

Mathematical research benefits everyone, because it creates a fertile field of ideas from which we can draw solutions to our problems. Mathematics education is the only hope that we have to continue our work; if there is not a sufficient mathematically educated labour pool in the future, then our work today is for naught. Despite the restrictions we believe may limit our action, we must ensure the future of mathematics in Pakistan.

Responsibility for promoting and improving mathematics in Pakistan rests primarily with academies.

If mathematics is to be properly supported by society, then mathematicians must not forget their obligations. Universities must go beyond measuring success only in terms of grants or publications, and researchers must recognise their larger obligations. If we cannot convince our greatest minds to tackle the vital problems of education, government and business, then society will invest elsewhere, and everyone will
government and business, then society
will invest elsewhere, and everyone will
be the loser in the long run.

Mathematics also suffers from a public relations problem. Pakistani researchers solve problems and advance theory on every frontier, but the general public (and often the government) does not appreciate these achievements.

If academics cannot convince the public that they are doing useful work and are solving problems that directly or indirectly affect everyone, then their other efforts will be in vain.

Can Japan Make Einsteins Too?

Courtesy of The Economist, August 11, 1990.

In a bid to become a leader in the sort of research that makes history, not just profits, Japan is spending more on basic science than ever before.

The Japanese are less creative than westerners. So say some Japanese, and some westerners, in an attempt to explain why a country that can make some of the world's most advanced electronic products has won fewer Nobel science prizes since the war than Switzerland. Japanese scientists, so the argument goes, lack the inventiveness to produce insight into the workings of nature. That ability seems to be reserved for European and American researchers.

Nonsense. Before the second world war Japan had excellent researchers. In 1935 a theorist called Hideki Yukawa, working at the prestigious Riken Institute near Tokyo, proposed a theory about the forces in the atomic nucleus for which he later won Japan's first Nobel prize. The reason that Japan has been lagging in basic science since then has little to do with the peculiarities of Buddhist thought or the Japanese group ethic. It has a lot to do with the way that institutes like Riken were starved of resources for years after the war.

The government's postwar plans had no room for dreamy boffins. The Ministry of International Trade and Industry (MITI) ensured that money for R&D was aimed at tangible results. The Ministry of Education, Science and Culture geared the universities to producing an army of competent but dull scientists and engineers for industry. These were the people who raised the status of "made in Japan" from the pejorative to the superlative. Now, having shown that it can use western technology, and in many areas outdo it, Japan wants to prove that it can make scientific breakthroughs too.

Research yen

At first sight the statistics look rosy. In the 1980s Japan overtook America to become the country which spends the largest proportion of its GNP on research and development. This year R&D investment will increase to over 2.9% of GNP, while American investment has fallen steadily since 1985 to 2.5%. Further, about half of government-financed research in America is military: in Japan practically none of it is.

But in America, government money accounts for over half of R&D, whereas in Japan the figure is only about 20%. And since the Japanese government's R&D money most often winds up in projects where there is little research and much development, Japan ranks as one of the stingiest supporters of basic science in the industrialised world. Researchers at Japan's universities struggle to keep abreast of developments in the West. According to Dr Akio Yamamoto of the Tokyo Institute of Technology, government support for university researchers has fallen 20% over the past 20 years, to about ¥8m ($53,000) per scientist.

Things have started to look up. Thanks partly to pressure from America, the finance ministry has let the science and technology budget increase in real terms for two years running—after nearly a decade of keeping in line with inflation. This year the increase in the budget was about 4% in real terms; bureaucrats are already talking of doubling government R&D funds to about 1% of GNP during the 1990s.

The money goes mainly to three government bodies: MITI, the education ministry and the Science and Technology Agency (STA), which runs Japan's nuclear-energy research, but has also branched out into space and other ambitious programmes. Although the education ministry gets about 45% of the government's R&D budget, most of it is used to keep the universities ticking over. The STA's share is a quarter, MITI's about 10%. In principle the R&D investment of the three bodies is co-ordinated by a Science and Technology Council. In practice they vie with each other to back the most attention-catching science initiatives—a bureaucratic game many scientists feel they can turn to their advantage.

Projects galore

One of the STA's most ambitious initiatives is a series of projects called Exploratory Research for Advanced Technologies (ERATO), each of which gives an outstanding Japanese scientist a five-year chance to set up a research group and develop a zany idea, with practically no regard to cost. Most of these projects have only a distant bearing on practical technology. Consider two examples.

The "superbug" project of Dr. Koki Horikoshi at the Tokyo Institute of Technology tracked down all sorts of odd bacteria that live in unpleasant environments. One of them, a triangular-shaped organism that thrives in water eight times as salty as the sea at 37°C, turns out to be a fairly close relation of one of the oldest bacteria known from fossil records. Dr. Horikoshi wants to isolate the genes that allow such bugs to survive, so that this resilience can be transferred to other bugs used in biotechnology. His goal remains a long way off.

Dr Humio Inaba and his team at Tohoku University have measured for the first time the extremely faint light produced by a germinating soyabean. Such "biophotons" are not the same as the glow from chemical reactions seen in fireflies. Much research remains to be done to understand the phenomenon. But a spin-off of Dr Inaba's efforts is an ultra-sensitive light detector bound to find applications elsewhere.

ERATO has been a roaring success, not just for the scientific results it produces, but because it supports the sort of western-style mavericks whom the Japanese feel they lack. Four new projects will be launched this year; ERATO's budget is now ¥5 billion ($33m), up 60% in four years.

One of MITI's pet projects is the International Superconductivity Technology Centre (ISTEC), based in Tokyo and Nagoya, which the ministry runs in collaboration with 80 Japanese companies. ISTEC was created in the frenzy of excitement that followed the discovery of a new type of superconducting material in 1986.

Superconductors carry electrical current without wasting energy, which makes them ideal for applications as diverse as micro-circuitry and industrial electromagnets. Normally they work only at extremely low temperatures, which are costly to maintain. The new variety works at temperatures which can be reached more cheaply. Much of the ¥5 billion that MITI will spend on superconductors this year will be aimed at technological development: the new high-temperature variety is a brittle ceramic in its raw state, and has to be made more pliable. But many researchers at ISTEC are also probing the whys, as well as the hows, of superconductivity. Too little is known to predict which combination of materials will make a good superconductor. For this work, the much-vaunted ability of Japanese researchers to slog away for years to make incremental improvements may be a boon.

One example is a promising variety of superconductor made of large organic molecules. Although the first organic superconductors were discovered over a decade ago, they worked only at abysmally low temperatures. In America and Europe initial excitement about organic superconductors died away with the discovery of the ceramic variety. But Japanese researchers plugged on, and discovered 11 different organic superconductors in 1988 alone. That year Dr Hatsumi Mori, now at ISTEC in Nagoya, synthesised an organic superconductor that worked at a temperature 2°C higher than the previous world record: quite a step, though it may not sound so.

Beyond Walkmen

Just when western companies have begun to extol the virtues of Japan's patient approach to technology, Japanese firms have been trying to inculcate their researchers with daring. Deciding how much corporate R&D money goes on fundamental research is difficult; Japanese companies sensibly eschew the distinction between basic and applied science. By government estimates, though, the investment was ¥400 billion ($3.1 billion) in 1987—up fourfold in a decade.

Company directors give several reasons for their new willingness to support basic research. There are claims of a noble desire to repay the West in kind for the ideas Japan borrowed to fuel its economic miracle. There is the pragmatic view that Japan cannot rely on western innovation for ever. And there is the cynical view that investing industry's profits in basic science can hardly be worse than seeing them eaten away by taxes. Whatever the truth—it is no doubt a mixture of all three—the consequence is that today about 10% of the R&D staff in the biggest high-tech companies are involved in research so long-term and risky that it can safely be called basic.

Perhaps the clearest indication of the Japanese change of heart is the Advanced Research Laboratory which Hitachi established in Saitama prefecture in 1985. The laboratory, with a staff of 100 scientists, is devoted to the sort of esoteric basic research that makes product managers shudder (see *Hitachi's quantum holograms*). Ironically, Hitachi has built the laboratory, which is clearly in the style of AT&T's famous Bell laboratories, at the same time many American companies are trying to emulate the Japanese by integrating their basic and applied research.

Sunrise on science city

More typical of most Japanese companies' investment in fundamental research is a laboratory that NEC recently opened in Tsukuba science city, outside Tokyo. Over half the scientists there are involved in long-term research. One group interested in artificial intelligence has been peering down microscopes at the nematode worm, *Caenorhabditis elegans*. Many artificial-intelligence researchers are captivated by the idea of computers based on the "neural networks" of the brain. NEC hopes that the nematode will prove an example simple enough to show how such networks operate.

At the beginning of the 1980s Tsukuba consisted of some 50 government research institutes transplanted to paddy fields outside Tokyo. Companies were slow to follow, but the infrastructure built for a Science Expo held in Tsukuba in 1985—shopping malls, restaurants and so on—made the place more attractive. In the past five years over 60 companies, both Japanese and foreign, have established R&D labs there.

Encouraged by its success, and eager to spread research institutes more evenly across the country—at present about half of all Japanese researchers are in the Tokyo area—the government is trying to develop a second science city between Osaka and Kyoto in the Kansai region. It is less a city than a sprawling constellation of institutes; one of the more ambitious plans is for an Institute of Advanced Studies, modelled on the archetypal ivory tower in Princeton where Einstein spent his later years, which should open next year. The director, Dr Azuma Okada, has raised ¥7.5 billion ($50m) from industry and private investors.

Making history

Despite the investment by government and industry, Japan still has a lot of catching up to do, and some ingrained habits to change. Dr Susumu Tonegawa, who won Japan's first Nobel prize in medicine in 1987, but works in America, shocked his countrymen with scathing comments about the gerontocracy that runs their universities. Many Japanese scientists would agree, but—another problem—few dare say so openly.

On the bright side, Japanese researchers raced ahead of their British and West German colleagues in the 1980s to become the second most prolific in the world, with about 25,000 scientific publications a year (just under a quarter of America's output). Many of these are in Japanese, but the number of articles published by Japanese researchers in American journals is now up to about 10% of the total, from 2% a decade ago. Cautiously, Japanese scientists are also learning to be more critical. One American scientist at a recent conference in Osaka was amazed by the progress made in the five years since his last visit. Instead of the stone-faced silence that used to fill up the question time after talks, there was lively discussion.

Among the scientists now reaching the upper rungs in Japan's research establishment, many spent their formative years at top American laboratories. They try to inculcate a more independent spirit in their younger colleagues. Ideally, many Japanese scientists would like to see the whole education system reformed to encourage less rote-learning and more originality. But the chances of the staunchly conservative education ministry allowing that to happen soon are slim. Instead, Japanese science bureaucrats should probably tackle the problems that can be fixed quickly.

Some of the most frequently heard complaints might surprise westerners. There are too few laboratory technicians: in the universities the number has fallen from nearly one to each scientist 20 years ago to about one to three. Computer software is inadequate, partly because Japan lacks the myriad software start-ups American scientists rely on. The same goes for much of the more specialised experimental equipment, which must be imported. And then there is the dearth of young scientists and engineers. As in the West, Japan's brightest are attracted by larger salaries in the financial world.

Even if more money can ease many of these problems, some westerners may ask why the Japanese bother, since fundamental research is too far removed from the production line to be of direct economic value to the country that does it. But as the Japanese are only too aware, the quality of life is not measured in colour televisions alone. There is more to national pride than running a large trade surplus. Westerners take it for granted that the illustrious figures of modern science are European or American. It would do wonders for Japanese self-esteem if Japan could contribute more to the next century's history books than pictures of Walkmen and video cameras.

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Hitachi's quantum holograms

Dr Akira Tonomura of Hitachi's
Dr Akira Tonomura of Hitachi's
Advanced Research Laboratories has made a name for himself by studying an oddity of quantum physics known as the Aharanov-Bohm effect. For a researcher in a Japanese corporate laboratory, this is unusual work—about as pure as science can get without impinging on metaphysics. In the process of investigating this obscure effect, though, Dr Tonomura developed a technique for making holograms of magnetic fields using electron beams. This promises to shed light on the workings of high-temperature superconductors.

The effect was predicted more than 30 years ago by Dr. Yakir Aharanov and Dr David Bohm, both then at Bristol University in England. They had thought up a way to measure one of the most ephemeral entities in physics, the magnetic vector potential. Magnetic vector potentials were originally introduced into the theory of electromagnetism as a sort of mathematical shorthand, to simplify complicated calculations about electromagnetic fields. In classical electromagnetic theory, the strength of the magnetic vector potential at any point is arbitrary; only the way it varies from point to point matters. It was long believed that the magnetic vector potential was just an expedient theoretical tool.

However, when quantum mechanics was developed, the magnetic vector potential turned out to play an indispensable role. If this curious quantity is so important, Dr Aharanov and Dr Bohm reasoned, there must be circumstances in which it acts even when no magnetic or electric fields are present. The Aharanov-Bohm effect is a lot easier to sketch on the blackboard than to demonstrate in the laboratory. The main problem has been to convince sceptics that stray magnetic or electric fields are not affecting the experiments.

Dr. Tonomura and his team have provided the crucial proof. They fired an electron beam at a minute magnetic ring encapsulated in a superconducting material. One of the properties of superconductors is that they are perfect shields against magnetic fields, though not against the magnetic vector potential.

According to quantum mechanics, particles can be considered as waves; Dr
particles can be considered as waves; Dr
Tonomura's electron beam, then, can be considered as a set of ripples running down a stream. The magnet in the superconductor disturbs the ripples, thanks to the magnetic vector potential, like a rock in the stream. Downstream of the disturbance, the disturbed and undisturbed ripples start to affect each other. They produce an interference pattern of electron waves similar to the interference of light waves which produces the illusion of depth in holograms. The magnetic vector potential produces just the sort of hologram Aharanov and Bohm predicted.

For the experiment to produce unambiguous results, the superconducting ring had to be as small as possible. Here Dr Tonomura could rely on Hitachi's fancy chip-making equipment to fabricate one that was only a couple of microns across. Although Hitachi's R&D managers admit that there is no obvious practical value in demonstrating the Aharanov-Bohm effect, they like to boast about Dr Tonomura's achievement, which many scientists reckon is worth a Nobel prize.

The benefits of his work are not purely academic. Since his technique is sensitive enough to detect the elusive magnetic vector potential, measuring ordinary magnetic fields, even tiny ones, is easy. So Dr Tonomura has used his device to look at what happens when a superconductor starts to let magnetic fields leak through. This happens if the superconductor is not kept cool enough, or if the magnetic field is extremely strong.

The magnetic field appears in the holograms like a landscape of tornadoes above the superconductor's surface. Each tornado is known as a flux line. Researchers can watch how the lines change while the superconductor carries an electric current. If the lines slide along with the current, they dissipate energy, limiting the performance of the superconductor. This has proved to be a real hurdle for the many scientists trying to develop the high-temperature superconductors into useful products. Now the scientists can judge directly how successful they are in their attempts to "pin" the flux lines in place by various trial-and-error chemical tricks. Dr Tonomura's tale will delight those boffins who are keen to point out that
boffins who are keen to point out that
recondite research can bring practical rewards.

Development of Science and Technology in India

by Dr. Sabra Khatoon,
Aligarh Muslim University.

Science is not an unknown commodity in India. The ancient Indians had made significant contributions in astronomy, mathematics, metallurgy and medical science including surgery. However, science in the modern sense was introduced into India after the British occupation of our country. They had established universities at the three metropolitan towns of Bombay, Madras and Calcutta in 1857.

Sporadic research started in India mainly due to two individuals. They are J.C. Bose and P.C. Ray. P.C. Ray can be described as the torch bearer of scientific research in India. The scientific research was originally initiated in Calcutta, in its different institutions, such as Presidency College, Calcutta University, Indian Association for the Cultivation of Science and Bose Institute. The Indian Statistical Institute was later added to this list. There are several other institutions where notable scientific research had been carried out and is still being carried on.

India gained independence in 1947. It was fortunate that Jawahar Lal Nehru was our first prime minister. He and his successors have given tremendous support to the advancement of science and technology. We have now 150 universities and almost as many other research institutions of diverse kinds in the country. There are several bodies which are supporting science. The names of the Council of Scientific and Industrial Research (ICMR), Indian Council of Medical Research (ICMR), Indian Council of Agricultural Research (ICAR), Department of Science and Technology (DST), the Atomic Energy Commission etc. might be cited as examples. Active research work is being carried out in many institutions which are directly associated with these organizations. The University Grants Commission is a major body supporting academic and scientific activities in the Commission is a major body supporting academic and scientific activities in the Universities.

Science continues to play useful roles in India.

1. Development of basic research

The Variable Energy Cyclotron at Calcutta is getting upgraded, the Giant Meter-Wave Radio Telescope (GMRT) that is being set up at Khodad near Pune. When completed in 1992, GMRT will become the most powerful facility in the world for research in astronomy in the meter and decimeter wave bands. A radio telescope is being developed at Ooty which has a large collecting area and is one of the important elements of the Very Long Base-Time Interferometry (VLBI) antenna system.

The largest optical telescope, the Vainu Bappu Telescope in the country with 234cm primary mirror was completed and became operational in 1985 at Kavalur. It even surpasses the 188cm telescope at the Tokyo observatory, in performance.

The Indian Middle Atmosphere Programme (IMAP) began on January 1982 and was continued till March 1989. IMAP was the most comprehensive Indian programme on the atmospheric environment since it involved the participation of some 200 scientists.

A major goal for IMAP was to develop modelling capabilities. Unfortunately, this has not materialized. Modelling of ions and of several minor species has, however, been attempted.

Yet another project of significance is the design and development of an electron synchrotron at the Centre for Advanced Technology (CAT) at Indore. Planned in phases, in the first phase INDUS I is expected to deliver 450 MeV electron beam to generate UV radiation, subsequently to be upgraded to INDUS II to deliver 2 GeV electron beam to cover the X-ray region of the synchrotron beam for spectroscopic and condensed matter research as well as beams for various applications.

Two large projects which are recently commissioned are the Dhruva Reactor at Trombay and the Aditya Tokamak Device at Ahmedabad.

Another major experiment in basic science in the highly competitive field of particles is in progress at Kolar gold fields.

Research and development in

Research and development in computer being in its infancy all over the world, India has a good chance of becoming world leader in software, with great export potential.

The physicist has continued to play a very important role because of his experimental quest towards a variety of new techniques and new instruments; the vistas continue to open up with developments in other fields like computer technology, robotics and material science. It is our hope that Indian physics and Indian science will forge ahead with greater vigour in this interdisciplinary interactive activity.

2. Instrumentation

The well known physicist Rabi once observed that everything is to the left of physics. This is an arrogant statement but certainly true so far the question of instrumentation is concerned. In the last century there was not much of an instrumentation industry in India, but in the middle part of this century, our own instrumentation industry is at par with the western world in quality, though perhaps not in quantity.

3. Aircraft industry

There is a growing aircraft industry which, besides producing, under license, batches of British and Russian aircraft, the Gnats and Migs, has also brought into service an Indian designed jet fighter, the HF-24. Indian designed radars and sophisticated electronic communication and other equipments are now in production in India. A Side-Looking Airborne Radar (SLAR) has been developed and has been fitted to an aircraft and test flights.

4. Nuclear energy

In some ways we seem to have done reasonably well in the field of nuclear energy. India was the first country in Asia, outside the USSR, to produce fuel elements for atomic reactors. It covers the entire nuclear cycle from exploration, mining, extraction, purification, and conversion of nuclear materials; production of fuel elements for reactors; the design and construction of power reactors and their control systems for units of 235 MW capacity; production of heavy water, health and safety instrumentation; reprocessing of spent fuel and waste management.

instrumentation; reprocessing of spent fuel and waste management.

India's first nuclear reactor which has the name Apsara, went into operation as long ago as 1956. Other reactors followed in quick succession.

5. Telecommunications

Telex service was first introduced in India between Bombay and Ahmedabad in 1956. But India started the R&D on electronic switching technology as early as 1965. In 1981 a "Committee on Telecommunications" was set up by the Government of India. It recommended the use of digital electronic technology both for transmission and switching for future development of India telecom network. Hence a beginning was made to modernise the telex network.

Accordingly, the Centre for Development of Telematics (C-DOT) was established in August 1984 to develop digital electronic switching system.

There are two basic ways commonly used in telecommunications by which a signal can be encoded with the desired information. They are analog and digital. An analog signal is a one-to-one representation of the original information. The electrical signal is analogous to the varying patterns of the information. Digital signals carry information discontinuously in the form of a set of discrete symbols or pulses whose value is determined by a code. More commonly, digital signals refer to a stream of pulse having only two values, '1' (pulse present) or '0' (pulse absent). The 1s and 0s represent a binary code, formed according to the rules of binary arithmetics.

Any type of information can be encoded in either analog or digital but digital signals are being increasingly preferred because these signals have far less noise and distortion and hence better quality than an analog signal. A digital channel can transmit digitalised voice, computer data, encoded visual information, telex and many other digital signals. This will make the networks of the future economically feasible.

India has found its own solution in switching systems technology. It has successfully created a range of digital switching systems through the efforts of its telecom R&D centre C-DOT. All the products by C-DOT such as PABX (Private Automatic Branch Exchanges),
the products by C-DOT such as PABX
(Private Automatic Branch Exchanges),
RAX (Rural Automatic Exchanges) and MAX (Main Automatic Exchanges) are indigenously designed and developed. It may be possible that the technology developed by India in the area of the switching systems is the solution for many developing countries.

Installation of electronic telex exchanges is a boost to India's telex network.

India's first and the world's largest automatic telecom surveillance and monitoring system IMSS-2000 was commissioned recently. This will be used for monitoring long distance networks. Satellites are also proving to be appropriate solutions to many telecom problems, especially regarding long distance transmission and remote sensing. India's INSAT is useful for this purpose.

India now has ambitious plans to expand the telecommunications network in the country. It proposes to commission about 2,111 route kms of fibre optic systems, 2560 route kms of coaxial cable systems, 2530 route kms of ultra high frequency (UHF) systems in the country. Also there is a plan to provide STD facility to 138 district headquarters, covering all the 447 district headquarters in the country.

Developing country like India cannot afford to lag behind the developed countries in the spread of fax culture. fax boom and explosion will occur in India, as the fax machines are becoming cheaper.

6. Space

India spends every year well over $400 million on its space programme which has been to develop skills and capabilities to design and building satellites, and satellite launch vehicles; to define areas of application such as telecommunications, broadcasting and remote sensing and to design and fabricate instrumentation for such application. The following are the various centres of the Indian space Research Organization (ISRO) and their roles in the country's space efforts.

(a) The Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram — The largest ISRO Centre. The VSSC's primary responsibility is the development of launch vehicles needed for the space programme.
development of launch vehicles needed
for the space programme.

(b) ISRO Satellite Centre (ISAC), Bangalore — The ISAC is responsible for design, fabrication, testing and management of all satellites. The Centre has built as many as 11 satellites for various missions.

Aryabhata, the first satellite was put into orbit using a Soviet launcher in 1975. Then the two Bhaskara Satellites and the Ariane Passenger Pay Load Experiment (APPLE) were also experimental satellites.

The Rohini was the first indigenous satellite to be put into orbit using and Indian launcher, the SLV-3 (Satellite Launch Vehicle). The three SLVs each lofted the Rohini satellite into space.

The Stretched Rohini Series (SROSS) satellites, carrying scientific payloads are launched by the ASLV (Augmented Satellite Launch Vehicle). The first of the IRS (Indian Remote Sensing) Satellites, the IRS-1A, was put into orbit in March 1988. IRS-1B is expected to be launched next year. The enhanced IRS-1C and IRS-1D are scheduled for 1993 and 1995 respectively.

The indigenous INSAT-I satellites will replace the current INSAT-I series made by the American company, Ford Aerospace. The first of the INSAT-II is scheduled for launching towards the end of 1991.

(c) Liquid Propulsion Systems Centre (LPSC), Valiamala and Bangalore. The LPSC has to develop all the liquid engines required for the satellites and launch vehicles. The LPSC provides the Reaction Control Systems for indigenous launch vehicles and satellites to maintain correct orientation.

(d) National Remote Sensing Agency, Hyderabad. It specialises in the practical application of remote sensing techniques.

(e) Space Applications Centre (SAC), Ahmedabad. The SAC provides many systems and packages used in satellites, such as the IRS cameras.

(f) SHAR Centre, Sriharikota. All indigenous launch vehicles lift off from SHAR. The solid motors used in the launch vehicles are cast at SHAR. Hence it has the Solid Propellent Space Booster Plant, the largest of its kind in the country.

(g) ISRO Telemetry Tracking and Command Network (ISTRAC). The
(g) ISRO Telemetry Tracking and
Command Network (ISTRAC). The
ISTRAC, with its headquarters in Bangalore and tracking station at Sriharikota, Thiruvananthapuram, Bangalore, Lucknow and Car Nicobar, supports ISRO's launch vehicle and satellite missions.

To sum up, we can say that in high technological skill and know-how, India can compete with anybody in the world. This will pave the way for leading a happy and comfortable life and bringing food, energy, health, education and employment within the reach of Indians.

Dr. Sabra Khatoon was a participant in the Condensed Matter Workshop 1990.

Appointments

News from ICTP welcomes communications on appointments and news on ICTP scientists for publication.

R.Z. Sagdeev Member of the Pontifical Academy of Sciences

Prof. Roald Zinnurovich Sagdeev has been appointed a Member of the Pontifical Academy of Sciences. It is the first Soviet member of the Academy ever.

Prof. Sagdeev worked at ICTP in 1965-66 as a research leader in plasma physics. He is now a Member of the ICTP Scientific Council.

Prof. R.Z. Sagdeev at the ICTP Scientific Council in 1989.

Enrique Martin del Campo Director of ROSTLAC

We learn that Prof. Gustavo Malek is
Director of ROSTLAC
We learn that Prof. Gustavo Malek is
leaving his post of Director of the Unesco Regional Office for Science and Technology for Latin America as well as the post of Caribbean and Unesco Representative to Argentina, Paraguay and Uruguay. Mr. Enrique Martin del Campo, a very well-known and distinguished Mexican engineer, will succeed Prof. Malek as from 1 October.

Visits to ICTP

V.V. Kostiouk

Prof. Valeri V. Kostiouk, Director of Science and Technology Department and Member of the Board on State Planning Committee of the Russian Soviet Republic and Professor (Doctor) of Technical Science, had a meeting with ICTP and TWAS officials on 5 September 1990.

He was accompanied by Dr. Claes Brundenius, Associate Professor at the Research Policy Institute in Lund, Sweden.

Prof. A.A.R. Elagib

On 13 September, Prof. A.A.R. Elagib, Minister and President of the National Research Council of Sudan, delivered the lecture "Some Great Challenges in Physical Sciences".

Prof. Arnaud (France)

Profs. P. Arnaud (Medical University of South Carolina, USA) and G. Chazot (Scientific Director of CIO, UNESCO, and professor of neurology at Hôpital Antiquaille, Lyon, France) had a meeting with ICTP officials on 19 September, to discuss the possibility of establishing a new international centre for science in Lyon.

IRFOP

As every year, the Trieste branch of the Italian state-owned company for Investment and Initiative for Vocational Training (IRFOP) organized a visit to the ICTP in the framework of its course on "Organization and Management of Vocational Training". Sixteen managers in charge of vocational training and research in ministries and industries in developing countries visited the Centre on 3 October.

Liceo Lollino, Belluno

Liceo Lollino, Belluno

Also young students are interested in the activities of the ICTP. The students of the school "A. Lollino" in Belluno (northern Italy) asked to visit the Centre on 17 October so as to complete their visit to the scientific institutions in the Trieste area.

Taka Hiraishi, UNEP

Mr. Taka Hiraishi, Co-ordinator of the Support Measures in the Office of the Environment Programme of UNEP (United Nations Environment Programme) in Nairobi, Kenya, was at ICTP on 26 October.

Conferences and Lectures

• Prof. Yu Lu, one of the permanent members of the ICTP Scientific Staff in charge of the Condensed Matter Research Group, presented two papers at the International Conference on Low-Temperature Physics—LT 19, in Brighton, UK (16-22 August 1990): the first one, on "Competition and possible coexistence of flux and RVB phases in the Y-J model", prepared in collaboration with D.N. Sheng and Z.B. Su, and the second one on "Momentum transfer between ^{3}He quasiparticles and surface via ^{4}He boundary layer", written in collaboration with Chengtai Wang.

Prof. Yu Lu also took part in the International Conference on Science and Technology of Synthetic Metals — ICSM '90 (2-7 September 1990, Tübingen, Germany) with the paper "Lattice relaxation studies of polaron and exciton dynamics in M-X chains" which was prepared in collaboration with C.L. Wang, G.L. Gu and Z.B. Su.

• Profs. J. Eells and A. Verjovsky, the Members of the ICTP Scientific Staff in charge of the Mathematics Research Group, were invited by the Mathematics Department of the University of Porto (Portugal) to deliver lectures. Prof. Eells spoke on "Exponential harmonicity", while Prof. Verjovsky presented paper on "Totally geodesic foliations on hyperbolic manifolds".

• Prof. M. Tosi, in charge of the Condensed Matter Research Group, was
• Prof. M. Tosi, in charge of the Condensed Matter Research Group, was
Director of the Third International Bodrum School of Physics "Highlights of Condensed Matter Theory" (26 September - 5 October 1990, Bodrum, Turkey), during which he also presented three lectures on the liquid state.

Prof. Tosi was also invited to the 76th Annual Meeting of the Italian Physical Society (8-13 October 1990, Trento, Italy) to present the plenary conference "The liquid-solid transition: theoretical developments".

• Drs. F. Brambila and A. Alonso, both visiting mathematicians at ICTP from Mexico, presented a paper on "LP-continuity of conditional expectations" at the Latinoamerican Congress on

Probability, Mexico City, Mexico (24-29 September 1990). The paper was published as ICTP Preprint 90/117.

• Prof. A.A. Bakasov, a visiting mathematician from the Joint Institute for Nuclear Research in Dubna, USSR, was invited, while in Italy, to give seminars at three important Italian institutions — at the National Optics Institute (Florence), the Section of Applied Theoretical Physics of Milan University and at the Department of Physics of the Polytechnic in Turin. The titles of the seminars were: "Quantum fluctuations against Lyapunov stability", "New rigorous results in standard laser models and overlaps and differences between these models" and "On the phase transition in two-photon system and on the possibility of two-photon superfluorescence".

• Prof. N.H. Anh, Visiting Mathematician from Viet Nam, was invited at Nice University (France) to deliver a lecture. The title was "Groupes de Lie unimodulaires ayant une série discrète: algèbres enveloppantes et formule de caractères".

Activities at ICTP in September-October 1990

Title: RESEARCH WORKSHOP IN CONDENSED MATTER, ATOMIC AND MOLECULAR PHYSICS, 18 June - 28 September 1990.

Organizers: Professors P.N. June - 28 September 1990. Organizers: Professors P.N. Butcher (University of Warwick, UK), H. Cerdeira (Universidade Estadual de Campinas, Brazil, and ICTP, Trieste, Italy), F. Garcia-Moliner (Instituto de Ciencias Materiales, Madrid, Spain), I.M. Khalatnikov (Landau Institute for Theoretical Physics, Moscow, USSR), S. Lundqvist (Chalmers University of Technology, Göteborg, Sweden), Chi Wei Lung (Institute of Metal Research, Academia Sinica, Shenyang, P.R. China), N.H. March (University of Oxford, UK), K.S. Singwi (Northwestern University, Evanston, USA), E. Tosatti (International School for Advanced Studies, ISAS-SISSA, and ICTP, Trieste, Italy), M.P. Tosi (University of Trieste and ICTP, Trieste, Italy) and Yu Lu (Academia Sinica, Beijing, P.R. China, and ICTP, Trieste, Italy).

Lectures: Group activity on defects and mechanical properties: some applications of the computer simulation of lattice defects to the understanding of mechanical performance; fitting of experimental log viscosity against log shear rate curves to constitutive equations; unusual elasticity — isotropic system with a negative Poisson's ratio; the method of direct measuring the surface stress tensor in thin crystalline plates; structural investigation of mechanical alloyed Al-Fe system; hydrogen diffusion in metals with trapping at defects; ultradiffusion on hierarchical structures; a study of fractal dimension of fracture surface formed by stress corrosion cracking in high strength steels; anelastic relaxations associated with local disordering in grain boundaries; fractal crack growth. fast-neutron irradiation effects on the structure of metallic glasses; local order in amorphous alloys $Hf_{1-x}T_x$ (T=Cu,Ni); thermodynamical model for poling of ferroelectric ceramics; single activation energy model: a new approach to radiation damage annealing; a gauge field theory and a topological theory of dislocation and disclination continuum; nucleation theory on liquid metals and alloys; dislocation model of zirconia-toughened ceramics; experimental and molecular dynamic studies of grain boundary embrittlement for Bi-segregated copper bicrystals. Group activity on atomic physics. Group activity on semiconductor physics: screening in atomic physics. Group activity on semiconductor physics: screening in superlattices; metal films; semiconductor LDS; Martree and exchange energies in a confined electron gas; Bohm-Aharanov effect; electronic structure of strained layer semiconductor superlattices; nonequilibrium phonons in semiconductors; Coulomb blockade; the properties of semiconductor/electrolite interfaces; self-supporting acousto-electronic pulses driven by optical excitation of semiconductors; calculation of partition function as a nonlinear mapping problem; studies of temporal characteristics of the resonant tunneling in double-barrier quantum wells; electronic structure of Ge_n/Si_n strained layer superlattices; magnetoconductance of mesoscopic rings in a tight-binding model; Auger recombination in low-dimensional systems; localization and the integer quantum Hall effect; electronic structure of deep centres in semiconductors; magnetotransport in n-GaAs and n-$Al_xGa_{1-x}As$ in high magnetic fields under hydrostatic pressure: effects of EL2- and DX-defects near the metal-insulator transition; study on properties of semiconductors using diamond anvil cell; spin fluctuations in 3D metals in paramagnetic phase; the optical nonlinearity and the effects of electron-electron interaction on the band structure in semiconducting polymers; MIS solar cell — a brief review; phonons and polaron-pair photoconductivity of conjugated polymers; self-consistent field effects and many-particle interactions in tunnel Schottky-barrier junctions (theory approach and experimental results); electronic signature of metal-semiconductor interfaces; a technique for distinguishing properties of Silicon and Germanium semiconductors. Group activity on surface physics: electronic structure of chemisorbed molecules; prototype system: CO on metals; crystal growth by deposition processes; growth of rough surfaces: a large scale simulation; extended versions of the Frenkel-Kontorova model; roughening of (110) surfaces of metals; perturbation of the electronic structure of adsorbate by local surface fields; morphological transitions in Laplacian growth; structural studies on adsorbed films; on the possibility of photostimulated phase transitions in structure of atoms adsorbed on semiconductor surfaces; numerical transitions in structure of atoms adsorbed on semiconductor surfaces; numerical solution of a structure equation of crystal growth; surface electronic response functions; on surface melting; kinetic roughening transitions and crystal shapes; resonance image states at (111) metal surfaces; experiments on surface melting; thermal fluctuations of crystal shapes; simple growth models; electron properties of adsorbed clusters (theory); avalanches, scaling and noise spectra; two fluid interface in porous media: experiment on kinetic surface roughening; inhomogeneous growth of rough surfaces.

Plenary Seminars: Lattice static calculations of defects and a discussion on the embedded atom method (EAM) type interatomic potentials. Chaos in time-delayed systems. Bonding and atomic structure of Mg_n clusters: a density functional molecular dynamics study. Thermoelectric power of high T_c superconductors. Vibrational and electronic properties of percolation clusters and quasicrystals. Growth kinetics in disordered systems. Maximum entropy principle in quantum optics problems. Incommensurate-incommensurate phase transitions. Macroscopic quantum coherence and instanton Aharanov-Bohm effect. Quantum chromodynamics for physicists far from it. Orientational ordering as a possible mechanism for viscosity enhancement of supercooled liquids. Asymptotic-time symmetry breaking in the symmetric spin-boson model: rigorous results and discussion of approximations. Some aspects of quasicrystals. Influence of quasiperiodic order on physical properties. Electric field induced solidification. Extension of the RPA theory of ferromagnetism in a magnetic field applicable at all temperatures. Microscopic calculations on liquid He^4 and He^3. Elementary symbolic dynamics. Decay of a metastable state (the Kramers problem). Quantum wave propagation through random and incommensurate systems. Survey of experiments on expanded and near-critical metals. Survey of experiments on metal-molten salt solutions. Thermodynamics and ionization kinetics of dense plasmas of the light elements. Defects in HCP crystals. Orbitals, correlations, valencies in high-T_c superconductors. Wigner crystallization with and without in high-T_c superconductors. Wigner crystallization with and without magnetic field. High frequency transport in quantum wires and heterostructures. Spin-orbit interaction in 2D electron gas. Image, surface and quantum-well states in metals. Periodic resonances in electron and photon spectra. Dissipative polarization by slow electrons. Quantum transport in ballistic microstructures. Superconductivity in doped antiferromagnets. Magnetic susceptibility of many valley two-dimensional electron gas: an application of 2+1 QED. Analytical theory of dendritic crystallization. Fluctuation theory of hydration forces and interaction of lipid membranes. Conducting polymers: optical and magnetic properties. Four wave mixing in opaque media (localization in nonlinear media). Correlation effects in rare-earth compounds. Concentrated Kondo systems and heavy fermion band magnets. Dynamical properties of quasicrystals.

Miniworkshop on Low-density Metals: Wigner transition. Dielectric anomaly close to metal-insulator transition in low-density metals. Excess electrons in metal-metal halide solutions. Are simple metals (alkalis) really all that simple? Theory of expanded fluid alkali metals. Metal-insulator transition in small Hg_n particles. Metal-molten salt solutions: survey of theoretical modelling. Clusters and magnetism of low-density metals. Quantum molecular dynamics study of dense hydrogen systems: a new approach.

The Workshop was attended by 408 lecturers and participants (298 from developing countries).

Title: WORKING PARTY ON ELECTROCHEMISTRY – CONDENSED MATTER ASPECTS, 27 August - 7 September 1990.

Organizer: Prof. A.A. Kornyshev (A.N. Frunkin Institute of Electrochemistry of the Academy of Sciences of the USSR, Moscow, USSR).

Lectures: Electrochemistry as a physical science. Electrochemical physics. Condensed matter physics for electrochemistry. Molecular theory of liquids and solutions. Concentrated ionic liquids. Nonlocal electrostatics for liquids and solutions. Concentrated ionic liquids. Nonlocal electrostatics for electrochemistry. *Experimenta crucis* in simulation of ionic solvation. Ion-molecular double layer. Molecular compact layer. Electronic structure of metal surfaces and metal/adsorbate systems: Kohn-Sham calculations. Metal electrons in the double layer theory. Electrochemical interface: new applications of the jellium model. In situ scanning tunneling microscopy. Theory of underpotential deposition. Many-body theory of specific ionic adsorption. Surface states and adsorption at the metal-electrolyte interface. The semiconductor-electrolyte interface. Solvent adsorption at the electrode/electrolyte interface. The role of the metal. The 1st coordination shell of Indium ions in very concentrated aqueous solution. Raman and X-ray diffraction studies. Influence of dielectric friction and electric saturation on the specific ionic conductance. Structure of polyelectrolytes. Applications of laser induced temperature jump in electrochemistry. Adsorption of water on metal surfaces: what do we know from high vacuum measurements and quantum chemistry calculations? Experimental studies of molecular adsorption. Adsorption in electrochemistry. Electrodynamics of electrochemical interface. Optical studies of electrochemical interface. Electrodynamics of rough surfaces and interfaces. Nonlinear optical phenomena and photoemission at the electrochemical interface. Second harmonic generation at metal-vacuum and metal-electrolyte interface: theory and experiment. Charge transfer in condensed media: an overview. Solvent dynamics in charge transfer. Quantum electrode kinetics. Experimental studies of the elementary act of homogeneous and heterogeneous reactions. Electrochemistry at superconducting electrodes. Low temperature electrochemistry at normal conductor/frozen electrolyte interface. Fractal electrodes: interplay of physics and geometry. Aspects of electrode modification and electrocatalysis. Radio-tracers technique for adsorption studies. Power sources. Solar energy conversion. Convective mass transfer in electrochemical cells. Electrochemistry for the study of turbulence. A molecular picture of $\varepsilon(k)$. Solvation dynamics in associating liquids. A new model of picture of $\varepsilon(k)$. Solvation dynamics in associating liquids. A new model of electron transfer at semiconductor/electrolyte interface. Adsorption isoterms on fractal electrodes. The influence of the ultrasound on electrode potential. Fundamental and applied electrochemistry versus atomi, molecular and condensed matter physics.

The Working Party was attended by 69 lecturers and participants (35 from developing countries).

Title: THIRD INTERNATIONAL CONFERENCE ON "APPLICATIONS OF PHYSICS IN MEDICINE AND BIOLOGY" — MEDICAL DIAGNOSTIC IMAGING (GIORGIO ALBERI MEMORIAL), 4 - 7

September 1990.

During the Conference, the Third World Association of Medical Physics — TWAMP — awarded the "First International Giorgio Alberi Prize", donated by the Giorgio Alberi Foundation, to the best poster contribution by a participant from a developing country.

International Advisory Committee: Profs. J.R. Cameron (University of Wisconsin, Madison, USA), L. Dalla Palma (University of Trieste, Italy), B. De Bernard (University of Trieste, Italy) and S. Lin (Unità Sanitaria Locale, Trieste, Italy).

Organizing Committee: Profs. P. Baxa (University of Trieste, Italy), E. Castelli (University of Trieste, Italy), F. De Guarrini (Unità Sanitaria Locale, Trieste, Italy), G. Moschini (University of Padua, Italy) and R. Renzi (University of Florence).

Course Directors: Dr. A.M. Benini (Ospedale Maggiore, Parma, Italy), Prof. L. Bertocchi (ICTP), Prof. R. Cesareo (Centro per l'ingengeria biomedica, University of Rome, Italy), Prof. A. Farach (University of South Carolina, Columbia, USA) and Prof. S. Mascarenhas (Universidade de São Paulo, Brazil), with the co-operation of the Istituto Nazionale di Fisica Nucleare (INFN, Italy) and Società Italiana di Fisica (SIF, Italy).

Lectures: Nuclear magnetic resonance: state of the art. Nuclear magnetic resonance: methodological developments. Human in vivo localized MR spectroscopy: approaches and various results. Image-guided in vivo MR spectroscopy: approaches and various results. Image-guided in vivo MR spectroscopy. Nuclear magnetic resonance: imaging. Nuclear magnetic resonance: flow. The basic ideas of acupuncture therapy. Digital radiography: present detectors and future developments. Time and energy subtraction techniques in digital radiography. Digital radiography: X-ray lasers. Digital radiography: advanced CT. Advanced technology: ultrasound. Advanced technology: biomagnetism. SPECT: physical principles and future developments. Nuclear medicine: PET. Nuclear medicine: nuclear cardiology. Electrical Impedence Tomography.

The Conference was attended by 167 lecturers and participants (29 from developing countries).

Title: COLLEGE ON MEDICAL PHYSICS, 10 - 28 September 1990.

Organizers: Dr. A. Benini (Ospedale Maggiore, Parma, Italy), Prof. R. Cesareo (Centro per l'ingengeria biomedica, University of Rome, Italy), Prof. A. Farach (University of South Carolina, Columbia, USA), Prof. S. Mascarenhas (Universidade de São Paulo, Brazil) and G.C. Ghirardi (University of Trieste, Italy), with the co-sponsorship of the Direzione Generale per la Cooperazione allo Sviluppo (Ministry of Foreign Affairs, Rome, Italy).

Lectures: Introduction to the College. The programs of WHO. Interaction of radiation with matter. Principles of dosimetry. Technical parameters of X-ray equipment. Physical principles of tomography. Physics of radiological imaging. Interaction of radiation with matter. Principles of radioprotection. Physics of radiological imaging. Reconstruction methods. Dosimetric techniques and instrumentation. Electrets, photoacoustics, piezoelectricity. Principles of radioprotection. Quality assurance in X-ray units. Quantitative analysis of diagnostic images. Imaging treatment. Physical principles of MRI. MRI-instrumentation. Introduction to Monte Carlo methods. Application of MRI to arterial flow. Nuclear medicine equipment. QC on CT scanners. Radioprotection and QC in nuclear medicine. Introduction to MRI practical work. Physical principles of biomagnetism. Physical principles and work. Physical principles of biomagnetism. Physical principles and instrumentation of ultrasound scanners. Principles of ESR. ESR dosimetric techniques and instrumentation. QC in mammography: a survey in Italy.

Laboratory sessions: Use of the RX tube. Operative measurements in X-ray diagnosis. Mini CT-scanner. Software for image reconstruction. QC of diagnostic radiography equipment. Dosimetry and instrumentation. Image analysis with MATROX card. QC of CT and RX instruments. MRI-spectrometer (PILSCH).

The College was attended by 101 lecturers and participants (38 from developing countries).

Title: SCHOOL ON QUALITATIVE ASPECTS AND APPLICATIONS OF NONLINEAR EVOLUTION EQUATIONS, 10 September - 5 October 1990.

Organizers: Profs. P. De Mottoni (University of Rome "Tor Vergata", Italy) and Li Ta-Tsien (Fudan University, Shanghai, China).

Lectures: Nonlinear evolution equations as models in physics and applied sciences. Function spaces and abstract linear evolution equations. Qualitative theory of ordinary differential equations. One dimension compressible viscous flows. Geometric applications of evolution. Linear evolution equations of mathematical physics: well-posedness, regularity and asymptotic behaviour. Semilinear hyperbolic systems and equations with singular initial data. Uniform finite parameter asymptotics of solutions of nonlinear evolutionary problems. Stationary states, travelling waves, and their stability for reaction-diffusion systems. Singularity of solutions of the Navier-Stokes and von Karman systems. A class of cooperative systems which are structurally stable. Hyperbolic systems with dissipation. Existence and uniqueness of solutions of Majda's model of dynamic combustion. On the Monge-Ampere equations. On asymptotic behaviour of solutions of some nonlinear equations at infinity. The role of multiple scales in perturbation expansions. Mathematical description of viscoelasticity. Compactness and monotonicity for nonlinear evolution equations. Classical and weak solutions of a viscoelasticity nonlinear evolution equations. Classical and weak solutions of a viscoelasticity model. Asymptotics of the heat equation. Nonlinear waves in non dispersive media — basic equations and properties. Nonlinear evolution equations as field theoretical models in some low dimensional physical systems. On the Cauchy problem for parabolic equations. On the nonlinear stability of dissipative fluids. Nonlinear evolution problems in geometry. Existence and non-existence theorems for the Chipot-Weissler equation. Comparison principle for the porous media equation with absorption. Asymptotic behaviour of solutions of the wave equation outside trapping obstacles. Propagation of nonlinear optical waves in layered structures. A remark on three-surface theorem. Global behaviour of classical solutions: lifespan, blow-up, decay. An introduction to geometric theory of fully nonlinear parabolic equations. The global smooth solutions and global attractors for some dissipative nonlinear evolution equations. Compressible viscous fluids. Entropy consistency of large time step Godunov and Glimm schemes. Parametrically driven, damped nonlinear Schrödinger equation; stability diagram for the phase-locked solitons. Evolution problems of harmonic maps. A geometric theory for semilinear almost-periodic parabolic partial differential equations on R^N. Relativistic oscillator = q-oscillator. Lagrangian integration of hydrodynamics equations (new general method and classes of exact solutions). Some families of solutions of the Vlasov-Maxwell systems and their stability. Existence, uniqueness and iterative approximation of solutions to nonlinear Hammerstein equations. An existence theorem for nonlinear Volterra integral equation. Quasi-classical approach to ABC dynamics. Bifurcations and nonstability of differential equations. Nonequilibrium problems in phase-changes. Monotonicity formula and partial regularity results for the Yang-Mills flow. Well posedness and stability of initial-boundary value problems in atmospheric dynamics. Blow-up for equations with nonlinear dynamical boundary conditions. Global solutions of the nonlinear Maxwell-Dirac equations. Group theoretical approach to nonlinear differential equations. The existence of positive solutions for semilinear elliptic equations.

positive solutions for semilinear elliptic equations.

The School was attended by 200 lecturers and participants (87 from developing countries).

Title: COLLEGE ON NEUROPHYSICS: "NEURAL CORRELATES OF BEHAVIOUR, DEVELOPMENT, PLASTICITY AND MEMORY", 1 - 19 October 1990.

Organizers: Profs. A. Borsellino (International School for Advanced Studies, SISSA, Trieste, Italy), J.H. Kaas (Vanderbilt University, Nashville, USA) and O. Siddiqi (Tata Institute of Fundamental Research, Bombay, India), with the co-sponsorship of the Direzione Generale per la Cooperazione allo Sviluppo (Ministry of Foreign Affairs, Rome, Italy) and the International School for Advanced Studies (SISSA, Trieste, Italy).

Lectures: Brain evolution. Neural Darwinism. Motion computation and visual orientation in insects. Neurons as monads. Vision in Drosophila: conversion of the retinal image into a stack of sensory map. Models of primary pattern formation: the role of self-enhancement and long range inhibition. Gene activation and cell determination, segmentation and formation of net-like, branching structures. Vision in Drosophila: flight control by evaluation of the movements of figure and ground. Selective attention. Computational approach. Learning and networks, and applications. The formation of substructures: the initiation of eyes, legs and wings. Interhemispheric communication and differentiation. Vision in Drosophila: functional flexibility; search and choice. Auditory information processing. The hippocampal CA3 system as an autoassociator. Plasticity in olfaction. Parallel organization of the primate visual system. Afferent influences on auditory system development. Specification of cortical areas. Binaural interaction in the long-latency auditory off-responses: connection to sound lateralization by means of interaural intensity differences. Neural correlates of attention in the visual system. Organization of the auditory system. Neuromagnetism. Remarks on spatio-temporal dynamics of EEG. On the spectral dynamics of EEG. Rules of

temporal dynamics of EEG. On the spectral dynamics of EEG. Rules of

development deduced from misrouting sensory pathways. Plasticity of sensory maps in adults. The role of trophic factors in development. The somatosensory system. The formation of sensory maps. The problem set by Pascal's mother. Development of projections from the eye to the brain. Human vs. artificial intelligence — state of the art. Optimal design principles. Development of the neocortex. Retinal correlates of visual development. Organization of agranular frontal cortical areas in primates. Organization of the visual system. Mesial agranular frontal areas: their role in motor control. Psychophysics, signal detection theory and information theory. Functional differences in On and Off retinal pathways. Colour and topology in early vision. Inferior area 6: functional organization. Single cell recording and psychophysics. Long term potentiation (LTP). Lateral masking and demasking in vision. LTP and potassium channels. Specific protein phosphorylation. Synaptic plasticity and development. Strategies for perturbation of the function and the development of neural networks. Task determined visual strategies. Are there superprogrammes in the brain?

The College was attended by 94 lecturers and participants (31 from developing countries).

Title: COLLEGE ON "THE DESIGN OF REAL TIME CONTROL SYSTEMS", 1 - 26 October 1990.

Organizer: Mr. C. Verkerk (CERN, Geneva, Switzerland). Prof. A. Colavita (Argentina/ICTP) acted as Head of the Laboratory. Co-sponsorship of the Direzione Generale per la Cooperazione allo Sviluppo (Ministry of Foreign Affairs, Rome, Italy) and United Nations University (Tokyo, Japan). In co-operation with the International Centre for Science and High Technology (ICS, Trieste, Italy).

Lectures: Recall of 6809, Rosy. Programming in C language. Real-time operating systems and OS-9 for the 6809. D-A, A-D conversion. Structured design. Project hardware and software. Interfacing to IBM-PCs — hardware and software. UNIX. Analysis and visualisation of results. MINIX. Case

software. UNIX. Analysis and visualisation of results. MINIX. Case

study from telephony. Parallel processing. Extensions to OS-9. Case study. Review of DSPs, RISCs etc.

Laboratory exercises: Get acquainted with OS-9. Exercises in C. Exercises in C using Colombo 84. Start of project work. Project.

The College was attended by 79 lecturers and participants (48 from developing countries).

Title: WORKSHOP ON ATMOSPHERIC LIMITED AREA MODELLING, 15 October - 3 November 1990.

Organizers: Profs. G. Furlan (University of Trieste, Italy), A.D.

Moura (Instituto de Pesquisas Espaciais, São José dos Campos, Brazil), R.P. Pearce (University of Reading, UK) and S. Tibaldi (University of Bologna, Italy), in co-operation with the International Centre for Science (ICS, Tireste, Italy) and the World Meteorological Organization (WMO, Geneva, Switzerland), and with the co-sponsorship of the Direzione Generale per la Cooperazione allo Sviluppo (Ministry of Foreign Affairs, Rome, Italy) and of the Italian National Research Council (CNR, Rome, Italy).

Lectures: Primitive equations. Vector machines. Numerical techniques for solving the primitive equations. The concept of parameterization in numerical models. Convective parameterization. General overview of limited area modelling. Dynamical adaptation. Statistical adaptation. Surface transfer and turbulence. Objective analysis. Large-scale versus meso-scale predictability. Convection parameterization problems. Semi-Lagrangian integration techniques and variable mesh. Lateral boundary conditions. Finite-elements' methods (horizontal and vertical). Tropical cyclone track predictions with LAMs. Application of an economical split-explicit time integration scheme to a multi-level LAM. ICE pilot activities. LAM activities in India. Convection: new topics and open questions. Current stand of land surface modelling and air-sea reactions. Spectral methods. Enhanced orography. Tropical data assimilation. General problems of data assimilation. Specific problems of LAM/meso-scale. Vertical coordinates. Advection schemes: semi-Lagrangian, shape preservation, positive definiteness. Advanced surface treatment. Radiation.

Practical computer sessions: Numerical techniques for solving the primitive equations. Differential equations.

Seminars: The LAM experience in Kenya. LAM usage for short-range prediction of Asian summer monsoon. Down-stream semi-Lagrangian method. New approaches to future models in Australia. LAMs in developing countries with computers of limited power. Technology transfer activities. The LAM experience at ERSA-SMR of Emilia Romagna. Technology transfer activities. Transfer of LAM technology to developing countries. New approaches to future models in Japan. New approaches to future models in Canada. A frontier debate: where should LAMs go?

The Workshop was attended by 76 lecturers and participants (32 from developing countries).

College on medical physics, 10 - 28 September 1990.

College on neurophysics: "Neural correlates of behaviour, development, plasticity and memory", 1 - 19 October 1990.

College on "The design of real time control systems", 1 - 26 October 1990.

Workshop on atmospheric limited area modelling, 15 October - 3 November 1990.

Activities at ICTP in 1990-91

1990

Third autumn course on mathematical ecology .... 29 October – 16 November
Workshop on earthquake sources and regional lithospheric structures from seismic wave data .... 19 – 30 November
Workshop on composite materials .... 26 November – 7 December
Experimental workshop on high-temperature superconductors and related materials (advanced activities) .... 26 November – 14 December
First International School on Computer network analysis and management .... 3 – 14 December

1991

1991

Second college on theoretical and experimental radiopropagation physics .... 7 January – 1 February
Fifth international workshop on computational condensed matter physics .... 16 – 18 January
Winter college on "Multilevel techniques in computational physics (Physics and computations with multiple scales of lengths) .... 21 January – 1 February
Second training college on physics and technology of lasers and optical fibres .... 21 January – 15 February
Experimental workshop on high temperature superconductors and related materials (basic activities) .... 11 February – 1 March
Winter college on ultrafast phenomena .... 18 February – 8 March
Second ICTP-INFN course on basic VLSI design techniques .... 18 February – 15 March
Workshop on mathematical physics and geometry .... 4 – 15 March
ICTP-WMO international technical conference on long-range weather forecasting research .... 8 – 12 April
Spring school and workshop on string theory and quantum gravity .... 15 – 26 April
Course on "Oceanography of semienclosed seas" .... 15 April – 4 May
Fifth workshop on perspectives in nuclear physics at intermediate energies .... 6 – 10 May
Spring college in materials science on "Nucleation, growth and segregation in materials science and engineering" .... 6 May – 7 June
Trieste Conference on quantum field theory and condensed matter physics .... 13 – 16 May
Third ICFA school on instrumentation in elementary particle physics .... 20 – 31 May
Structural and phase stability of alloys (Adriatico Research Conference) .... 21 – 24 May

For information and applications to courses, kindly write to the Scientific Programme Office.

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