Conference Reports

Lindau Welcomes Nobel Physicists

The ancient German town of Lindau was at its best when, from 28 June to 2 July, the Nobel Prize physicists met there for the ninth time. It was also the 26th reunion of Nobel Prize Winners, and by a now firmly established tradition, an occasion when students and young scientists could meet eminent men of science in the conference hall and informally outside. 322 young scientists had registered : 262 from the Federal Republic of Germany, 32 from France, 11 from Austria, 10 from the UK and 7 from Switzerland, but more crowded into the Stadttheater for the morning lectures.

The reunions are financially supported by contributions from governmental and public bodies, institutions and private industry. But the current financial stringency is casting its shadow over Lindau and it is to be hoped that additional backing from new sources will be forthcoming, not only to allow these unique meetings to continue but also to enable more young people from a wider range of countries to attend.

Science, Energy and Armaments

Under this title, Hannes Alfvén opened the series of lectures. Speaking not merely as a prophet of doom he appealed to mankind and, in particular, the scientists to face and remedy a situation full of menace to our future. In the past, science was considered beneficial : science meant more knowledge, knowledge was good, hence science was good. Science-based technology has led to unprecedented growth in standards of living, but we have now become aware of the limits to growth and even if we may claim that new knowledge is still good, this cannot be said for all new technologies. Scientists, although unaccustomed to it, must accept a social responsibility in distinguishing between three types of development : what is good for society, what is bad and what is catastrophic for us all. It is good, for instance, to find out more about the cosmic and geophysical factors influencing life on Earth and to solve certain biological problems. Processes which are bad for the continued survival of mankind — uncontrolled growth in world population, increasing pollution, depletion of natural resources — must not be allowed to continue at present rates. Recirculation of our resources with the help of energy from cosmic sources (e.g. the Sun) should be planned for as soon as possible.

But Alfvén feels that the real catastrophe threatening the survival of man is the nuclear arms race with its consequent "omnicide". If other species have become extinct in the past why should man be an exception ? Thanks to his unique brain, man has been able to plan for the future and avoid threatening danger, but the problem of the survival of our species has never before had to be considered. The scientific community, this enormous think-tank, which has led us into this terrible situation must find an answer. Yet, out of the million or so qualified scientists and technicians active in the world today about 400 000 are employed in military research or development and only a few hundred seriously consider the large-scale problems such as "omnicide". Blame for the continued arms race is hard to apportion ; workers, scientists, industrial leaders, the military and ultimately the politicians are all driven along by a combination of social forces.

Deterrence, which is essential for the national security of the superpowers, assumes that those who control the bombs care for the lives of their civil populations. With the spread of nuclear energy there may soon be over twenty countries possessing atomic bombs and it is hard to believe that none of these nuclear arsenals will fall into the hands of unscrupulous people who would use blackmail, undeterred by prospects of retaliation. The balance of terror may not work very much longer. And, meanwhile, in spite of the present "overkill" capabilities, the arsenals grow by at least three nuclear bombs every day. Demonstrations, resolutions, international conferences have so far failed to halt or even slow down the arms race. Scientists in realizing their responsibility must clarify the situation to themselves and to the general public and try to find a way out. In conclusion Alfvén asked : will man be able to mobilize enough common sense, brain power and initiative to save himself from extinction ?

Beauty is in the Eye of the Mathematician

The opening speaker's appeal to the conscience of scientists in relation to the outside world contrasted with the almost introspective note struck by three following lecturers who considered the philosophy and thought processes underlying physics. P.A.M. Dirac talked about basic beliefs and prejudices in physics. Researchers must hold on to some basic beliefs which are still subject to discussion and criticism and they must be discarded as soon as they turn out to be prejudices : this is how important discoveries are made.

In Dirac's opinion, the best basic idea is to look for those relations that have great mathematical beauty, a principle already followed by de Broglie in relating particles and waves. To combine the ideas of quantum mechanics with relativity proved difficult. Non-relativistic quantum mechanics was inadequate as it could give probabilities that were not positive. Dirac in 1927, dissatisfied with this mathematically imperfect state of the theory, tried to find an equation applicable to particles at relativistic velocities. What he found led to a mechanics in which all the probabilities are positive and also resulted in equations providing for spin and magnetic moment of the electron — an unexpected bonus. This theory allowed for negative and positive energy, and one had to change one's ideas about a vacuum so that this was no longer merely empty space but a region where energy is a minimum. Each negative energy state is occupied by one electron, and positive energy states are unoccupied. The absence of a negative energy electron can be considered as equivalent to a particle carrying positive energy and charge. At that time the prejudice was that only two particles existed, the proton and the electron, opposite in charge but, unfortunately, with a big difference in mass. Dirac thought that the "hole" ought to have the same mass as the electron and confirmation came a few years later with the experimental discovery of the positron. How the climate of opinion regarding particles has changed since! Then people were prejudiced against new ones and nowadays everybody is only too willing to postulate more of them.

Behind the Count and Countess Bernadotte (centre) are from left to right (front row) : B.D. Josephson, A. Butenandt (chemistry), W. Forssmann (medicine), I. Giaever, R.S. Mulliken (chemistry), P.A.M. Dirac, G. Myrdal (economics) ; (second row) : H. Alfvén, A. Hewish, (Participant), W.E. Lamb, jr., L. Esaki, E.O. Fischer (chemistry), R.L. Mössbauer, A. Kastler, J. Rainwater. (Photo Pfeiffer)

Considerations of mathematical beauty also inspired Dirac's work on magnetic monopoles, but the theory lay dormant while experimenters failed to discover them. About a year ago, Price et al. claimed to have found one example of a monopole track in plates exposed to cosmic rays, but most physicists preferred an alternative explanation. Nevertheless some evidence is difficult to reconcile with the alternative explanation and so the search continues.

Mind over Matter

The youngest of the Laureates, Brian Josephson, dealing with the relation of intelligence and the mind to physics, rather startled his audience by proposing transcendental meditation as an experimental method. Intelligence, once predominantly within the domain of biological studies and interpreted as the product of evolution, is being considered increasingly from the viewpoint of the physicist. The interpretation of quantum mechanics owes something to interaction with the (intelligent) observer, and intelligence can be defined as a way of making a selection thereby significantly affecting the entropy of the environment. Intelligent behaviour can be shown to be the result of laws of thought and the question of the origin of intelligence, whether it preceded life and evolution could perhaps be solved through the study of these laws which are not inconsistent with the laws of physics. Thought processes have been investigated by Maharishi Mahesh Yogi and others partly on the basis of the Vedas, ancient writings, through transcendental meditation enabling a single observer to determine and note what goes on in the mind. Repeated experiments on consciousness would then lead to quantitative results and, perhaps, fascinating developments.

Causality and Chance in Physical Theory was the theme of Leon Cooper. Here again the mind of the observer entered into the picture. In Newtonian physics, future motion in a given force system is determined by initial position and velocity, and if the human mind is included as part of this physical world all things would be predetermined leaving no room for free will. Quantum theory overthrew this notion of causality. Schrödinger's wave function can only give us probabilities, and thus equal causes do not necessarily produce equal effects. Cooper developed an interpretation of quantum theory treating the entire observed system including the measuring apparatus and the mind of the observer in accordance with the Schrödinger equation. His diagrams illustrating a macroscopic event caused by the arrival (or not) of an electron at one of two detectors involved the sad fate of a caged cat (reputedly Schrödinger's) threatened with cyanide poisoning, where the sympathetic observer appeared to affect the interpretation of the underlying wave function. The non-causal theory developed shows that the wave function does not provide us with complete information about the present or the future. The passage from "possibility" to "actuality" occurs completely in the mind, and the real world as experienced by us is the result of interference between possible worlds.

Neutron Physics - Pure and Applied

Antony Hewish considered the extremes of physics studied by the astronomer, citing as one example the behaviour of large quantities of matter subjected to enormous gravitational forces. There, common matter (density about 5 g cm^{-3}) degenerates under pressure when its electrons are no longer trapped in their arbits and density reaches 1 ton cm^{-3} as in the "white dwarf" stars. Under the action of cosmic pressures even the nucleus can be destroyed ; protons and electrons combine into neutrons and the density may go beyond 10^9 tons cm^{-3} so that a teaspoon of this neutron material weighs as much as all the ships on our oceans. The existence of such matter with properties vastly different from anything that can be studied on Earth was predicted by Landau over 40 years ago, soon after the discovery of the neutron, but only the recent astronomical detection of neutron stars has confirmed it. Hewish discussed various models to account for the observed phenomena caused by extremes of density and pressure. To say that our physics is almost all done is far from the truth — astrophysicists are only beginning to tackle these immense problems and their quest towards ever larger things and the outer limits of space may ultimately help solve problems on Earth.

To have neutrons "hot" or "cold" on tap is greatly appreciated by many researchers in solid state and nuclear physics, chemistry, metallurgy and biology working at the High Flux Reactor of the Laue — Langevin Institute in Grenoble (see *Europhysics News*, **5** (June, 1974) 6.

Rudolf Mössbauer, the Director of this three-nation institute described its facilities which provide a wide spectral range of neutrons. Polished glass guides, some over 100 m long, with nickel deposited as reflecting material, take the neutrons at little loss from the vicinity of the reactor to areas where there is more space for experimental instrumentation, so that about 30 neutron spectrometers can be in simultaneous use and more are being erected. The personnel totals about 400 and as the Institute is intended to provide a service to external users, the local staff regrettably must be discouraged from having too many good ideas themselves so as to leave about 70 % of neutron beam time for experiments by outside institutes. Last year 535 experiments were carried out involving about 1200 visitors from 136 laboratories and 16 countries. Apart from constantly improving the performance of the installation much attention is given to the development of instrumentation and novel techniques. Work is also being done with polarized neutrons for which a particularly high flux is necessary. High resolution spin-echo spectrometers and other powerful devices are under construction and experiments with ultracold neutrons at about 500 Å are now being envisaged.

Lasers for Fusion

How to produce very hot neutrons, on the other hand, was described by Robert Hofstadter in his report on laser induced fusion. He has for some years given part of his time to this problem in collaboration with an industrial research laboratory, one of several engaged in this work in the USA. Thin-walled glass bubbles of less than a millimetre in diameter containing a mixture of deuterium and tritium are made to implode by an intense laser flash. Fluxes as high as 6×10^7 neutrons per event, greater than in any other laboratory process, have already been achieved. Most of the neutrons have an energy of 14 Mev, which proves them to be thermonuclear in origin. For these experiments the diameter of the pellets has been of the order of 100 μm so that an implosion caused by 100 joules which takes place in 100 ps represents 1 TW of energy. A three-to fourfold increase in laser power later this year should raise the yield by a factor of 100 or 1000. Liquid or solid fillings instead of gas used at present should prove better later on, and the size of the pellets could be increased once the techniques have been mastered.

"Classical and Quantum Treatments of the Duffing Problem in Nonlinear Mechanics" was the title of Willis Lamb's talk. To those of us who had never faced such a problem it soon became clear that Duffing had dealt with it in a 1916 textbook and that it concerned a forced nonlinear oscillator. Lamb had considered it in the early 60's during his work on the theory of masers and lasers where the interaction between radiation and matter is customarily treated as a problem of quantum mechanics. Adopting the classical mechanics approach, however, for which expressions relating driving force to the resulting frequency, amplitude and phase changes had been derived — which are just grist to the mill of computers — Lamb considered the radiation-stimulated atoms to behave as an anharmonic oscillator. One of the applications of lasers (whether socially useful or not) is for the purpose of isotope separation. The "illuminated" molecule is made to come apart by setting up vibrations of sufficient amplitude, and the selection of the isotope will depend on the laser frequency.

The separation of S isotopes from the gas SF_6 serves as a good example. The 7-atom molecule allows for 15 normal vibrational modes, requiring calculations of worthwhile complexity in classical mechanics to find the appropriate CO_2 laser frequency for the dissociation of the molecule. The Duffing problem helps to provide expressions for the forces between the atoms for any configuration of the molecule and a computer can then readily calculate the forces and plot resonance curves as a function of applied frequency. The results obtained are close to those yielded by quantum mechanical treatment.

Solid and not so Solid States

After lasers and computers another of the "harmless" toys of modern man was not forgotten : the semiconductor device. One of the pioneers in this field, Leo Esaki, spoke about recent investigations of multi-barrier tunnelling. In his introduction he mentioned that about a quarter of all physicists now work in the field of solid-state physics, where fundamental and applied research are strongly interlinked and science and engineering are well integrated. His own work in an industrial research establishment concerns the clarification of tunnelling phenomena, particularly in the case of double and multiple barriers. Extremely thin substrates are introduced into a GaAs type host crystal in ultrahigh vacuum by means of computer controlled molecular beams, so as to produce a periodic structure of equidistant barriers (superlattice). In these crystals a quantum-mechanical effect has been observed, which is due to the interaction of electron waves with the potential barriers. Practical applications of the strongly nonlinear characteristics found, including negative resistance, should not be long delayed.

The peculiar things that happen at, or close to one of nature's fundamental barriers, absolute zero, were discussed by Felix Bloch in remarks on super-fluidity. There ^{4}He refuses to solidify and, instead, adopts a state of exaggerated fluidity. His treatment of the persistent flow of helium round a thin circular tube used basic principles and also considered the case of the ideal Einstein-Bose gas not prone to super fluidity at finite temperatures.

Of Proteins and Protons

Ivar Giaever's theme at Lindau was surface physics and immunology. After his far-reaching work on the tunnel effect in solids for which he shared the 1973 Nobel Prize with Esaki and Josephson, he abandoned solid-state physics for new excitement in biophysics ("That's where the action is !"). The immunology system, which only vertebrates possess, is based on the reaction between the extraneous protein (antigen) and the specially produced defensive protein (antibody). Protein tends to stick to anything but not to itself or any other protein, except its proper antibody or antigen. So a proton monolayer can readily be formed on a metal surface but would only thicken where antibody sticks to antigen. Giaever, the trained physicist, revived the use of an optical instrument invented around 1880, an ellipsometer, for measuring the thickness and refractive index of the proton film. But perhaps to counter the feeling of the medical profession that physicists tend to make simple things too complicated, he also developed a simple device for clinical use, in which the immune reaction becomes visible to the naked eye. A glass plate coated with a film of indium particles will become less translucent when dipped into a protein solution because of the resultant monolayer of protein. Subsequent immersion into other proteins will have no effect unless they contain antibodies to the first protein when a second layer will further darken the plate. With this system of surface immunology quantities down to 10 ng/ml can be detected, whereas radioactive tagging is sensitive to 1 ng/ml. It has, nevertheless, already proved successful in clinical applications. Perhaps one day such a plate invisibly inscribed with the name of the disease from which you may be suffering (using an ink with the appropriate antibodies) could confirm the diagnosis if it reveals the name after being dipped into your blood.

In these few columns it has not been possible to more than sketch some of the general themes covered, but as conclusion we may repeat the quotation from a footnote in a German textbook on physics which states : "Every scientist is of the opinion that his own field of science is the most important one. This opinion is erroneous except in the case of physics which is truly the most important of all sciences".

S. Newman