The Graz Forum on Physics and Society,

Resolution and Recommendations

Graz, 21 April 2006

Science in general and **physics** in particular is one of the basic elements in our culture that sustain our communities. It is also a prerequisite for basic job skills and many of our daily functions. Science and physics are also the foundation for the high technology revolution seen in our societies and the way such technologies influence other societal challenges such as environment, energy supply, and communication and production technologies.

Forum Physics and Society, composed of high level physics representatives from 20 European countries and 7 countries outside Europe, has discussed the role of physics and its interaction with society. The Forum, being part of the Austrian EU-Chair program, was cosponsored by the European Physical Society and the World Year of Physics 2005 initiative.

The Forum notes the major challenges facing modern science and thus also physics. Globalization is putting pressure on the "physics enterprise". The linear innovation model was abandoned many years ago and more complex systemic models have been introduced, changing the way knowledge is produced, applied, and commercialised in social settings.

OECD studies show that a falling share of new tertiary graduates chooses physics as their field of study. Recognizing the central role of physics in the innovation process, the Forum stresses the importance of strengthening physics as a field of study and as a scientific profession. The Forum notes that these challenges are of a global nature and express commitment to address the challenges in Africa. Other regions present similar problems.

The Forum chooses to address five topics of importance for understanding the role of physics in society:

i) culture, ii) competitiveness and technology, iii) funding structures, iv) education, and v) ethical issues.

The Role of Physics in Society, Culture and the Sciences

Physics represents the rational analysis and accounting of the world we live in. It forms an essential part of human culture. Physics allows us to explore the world from the smallest to the largest objects. The application of physics is responsible for most of the basis of modern society and civilization, and it is essential that a large number of people in all parts of the world have some understanding of this subject. Electricity and electronics, now part of engineering, had their basis in previous physics discoveries. There is often a long time interval between basic discoveries and their applications to solving societal problems. Developments in many areas, including medicine, transport, communications, information technology and even the arts, have benefited directly from physics discoveries, and we are confident that physics and its methods will be necessary to solve many problems including those of the environment.

Physics is a good vehicle for international cooperation. Large and complex physics-based facilities are shared successfully between scientists from many countries. An outstanding example is the CERN Laboratory, formed by European countries only nine years after they had been fighting each other in World War II. In some ways this laboratory was a scientific forerunner of the EU. It is worth noting that this laboratory, whose task is to discover the fundamental constituents of the world and the forces through which they interact, invented the World Wide Web, and gave it freely to the world.

Physics education at all levels needs to be supported, particularly for women, both to ensure that all people understand the technological world in which we live, and the methods of physics in which observations and experimental results are incorporated into theories of the world, and also to provide the next generation of scientists and engineers who are greatly in demand in many sectors of the economy. The importance of physics education appears to be self-evident in a number of Asian countries, whose economies are boosted by the injection of scientific and technical know-how, and we urge the EU countries with their proud history of science to face up to this challenge. There is an urgent need for more teachers trained in physics, and those teachers who are not fully qualified in this subject need to be supported with appropriate materials and training.

It is encouraging that physics outreach activities and its popularisation as demonstrated in the 2005 World Year have increased the public's interest in science. In this respect, the role model of scientists, and particularly of physicists, within the population has been exemplified in the 2005 World Year of Physics. Many physicists have found their vocation as science communicators. We encourage a continuing dialogue between scientists and members of the public, which should be of mutual advantage.

We believe that important and challenging problems facing the world today are the threats of climate change and the anticipated global peaking of fossil energy production with the up-coming shortage of oil and gas.

These coincide with increasing global demand for energy originating from the presently less developed world. Intensive research and development of satisfactory clean alternative energy sources are urgently needed. The main candidates are biomass, hydro, nuclear, solar and wind power. Physics is an important provider of knowledge and methods of analysis concerning energy and environment, challenges that are with us today and will be with us on a time scale of generations. Mankind cannot afford to neglect to explore any possible energy sources.

Physics, Competitiveness and Technology

Recent studies have shown that over 40% of manufacturing employment in the UK is in industries based on physics (and physics-related engineering) and that this sector is growing faster than other manufacturing sectors. Similar effects can be expected for many other countries.

Areas of physics which are playing an important role in competitiveness include the energy sectors, medicine, materials and emerging areas such as information and communications technologies, photonics and nanotechnology. Physics gives the means for understanding a wide range of technologies and the ability to tackle problems from first principles when conventional approaches fail. Physics underpins engineering and its role in wealth creation. Physics also plays a major role in the present-day life sciences through the provision of techniques and equipment and as an important participant in these interdisciplinary fields. Notable techniques from physics used in medicine include MRI, PET scans, etc.

New technology requires basic research as it is not possible to predict where the new techniques will come from. History is full of examples of technology that has come from basic research in physics, e. g., electric power, X-rays, etc. Examples of recent developments that have come from surprising areas of physics include the World Wide Web and THz imaging developed to see through the atmospheres of planets and now used for security scanning to detect weapons, etc. under clothes. Knowledge of the fundamental laws of physics is the starting point for the majority of present-day and emerging technologies.

Industrial development is increasingly characterized by outsourcing, sparked off by a feeling of a lack of predictability and that the source of new ideas appears to be drying up. The challenge is international, as is physics, which serves as an innovative tool no matter where production is carried out. Industry is becoming increasingly global, relying on basic research performed around the world. Physics works on a global scale, dependent on the interaction of groups of physicists in different countries and regions. In Asia industry is expanding rapidly supported by greatly increased investment in the basic sciences, in physics in particular.

Unbiased and reliable research, essential for the long-term contribution of physics to economic competitiveness, requires international cooperation and an open exchange of information. Any serious conflict of interest with the later commercialization of results originating in such research should not arise as long as publicly funded research infrastructures themselves are not commercial competitors.

Needs in Research Policies and Funding

- The governments should accelerate the implementation of the Lisbon 2000 agenda and realize its objectives
- The research infrastructure including large-scale facilities should be distributed across Europe in a balanced way and combined with strong "home bases" as an interface for the cooperation. In eligible countries structural funds should be better used for this purpose
- Integration of the scientific potential of the new EU member states and the associated states should be accelerated
- The bottom-up principle of science funding should be kept for basic research and strengthened via the creation of the European Research Council
- The assessment of research output and impact should be put onto a more rational basis with the development of qualitative as well as quantitative indicators and analysis tools
- Researchers should be able to maintain their independence from political and commercial interests with proper consideration of societal needs and respecting ethical issues
- Serious attention should be paid to the quality of science administrators and to the reduction of bureaucracy by streamlining and developing best management practices
- A larger fraction of the EU budget as well as national funding should be spent on mathematical and physical sciences in accordance with tendencies in other major regions in the world
- The harmonization of the whole European R&D is important, but the presently proposed concepts of a European Institute of Technology are not the appropriate solution. On the other hand instruments exist to reach these goals (e.g. technology platforms and ERC)
- Physics pioneered international cooperation which should be strengthened to countries outside the EU including the developing countries

Education, Quality Assurance and Curricula

The Forum endorses the EPS position paper on Education, noting that physics educational issues are truly international.

The position paper emphasises that the physics educational system must master two important tasks: delivering physics-based scientific knowledge to all in elementary and especially in secondary schools, and providing tertiary research-based education to train the next generation of scientists for advancing science and for the needs of society.

The Forum endorses the Socrates/Erasmus programmes for exchange of high-school and university students and teachers and recommends extension beyond Europe.

Science education for women, particularly as it offers quantitative analysis of problems and the understanding of causality, is a critical factor for development. Women's particular role in early childhood education makes this especially important. Africa is an important example. There, science education for women can offer the opportunity to allow women to take decision-making control of their lives with respect, e.g. to health, work, and the future of their societies. This demands action from European countries and their physicists.

The Forum emphasises the importance of high quality physics teaching and teacher education.

Networking of physics teachers, teacher educators, physics education researchers and physicists is essential and should ensure that the rich variety of European physics teaching experiences is utilised. There is an urgent need for platforms where pupils, teachers and scientists come together, e. g., in the form of in-service teacher training, science centres and museums and science festivals.

The Forum emphasises that teaching should present physics as an international, creative and collaborative problem-solving effort, involving both men and women. Therefore, teachers must have a background in physics and have encountered scientists in action. The quality of physics education is threatened by a shortage of well trained teachers and the Forum strongly recommends measures to increase the attractiveness of the profession. Teachers must be given the opportunity to maintain their enthusiasm and the contact with developments in physics and physics education research.

The Forum stresses the importance that teachers have a voice in curricular reforms. These must be subject to pilot testing and evaluation before full-scale implementation.

The Forum recommends international collaboration in the setting of benchmarks for education and in developing research-based techniques for measuring learning outcomes.

The Forum notes the importance of rethinking the goals for both primary and secondary school science education to achieve "scientific literacy".

Scientific literacy includes a basic understanding of how science works and the capability for quantitative thinking. It also covers science-based knowledge for citizens in a society that needs to deal with many complex problems, often related to the resources of the Earth. Secondary school has to deal with socio-scientific issues, which often require expert knowledge in many different specialisations, calling for a multidisciplinary approach. The Forum appeals to governments to put more efforts on teacher training (initial and in-service) to enable teachers to realise these goals. It stresses the need for interdisciplinarity while doing justice to the specific characters of the different disciplines.

Ethical issues in physics

Upholding the highest ethical standards in physics is essential, in its research and teaching practices and in regard to its wider obligations to society. To this end the community of physicists needs to further improve its self regulatory practices. Physicists must accept personal responsibility to uphold the integrity of their science and to transmit its fundamental values to students and young researchers. The Forum acknowledges efforts developing appropriate codes of professional ethics.

To strengthen mutual trust physicists should engage in dialogue with their fellow citizens in order to share with them the excitement of scientific discovery and obtain a better understanding of currently felt needs and anxieties.

In order to further the quality and efficiency of physics research, authorities should refrain from any direct interference with its workings and only regulate its practices to the extent deemed absolutely necessary. Forms of funding should be agreed upon that minimize the risk of jeopardizing the integrity of physics research, professional standards, openness and good practice.

The participants of the Forum Physics and Society listed below unanimously support this resolution and recommendations:

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Draxler	Sonja	Austria	Austrian Physical Society
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