WORLD YEAR OF PHYSICS 2005: OPPORTUNITY TO LOOK IN THE FUTURE OF PHYSICAL INVESTIGATIONS AND SOCIETY CHALLENGES FOR PHYSICS

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Last year the 32nd session of the General Conference of UNESCO adopted a resolution supporting the initiative of 2005 as the World Year of Physics (WYP2005). The reasons of the General Conference of UNESCO for that were the following:

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

On this basis the General Assembly of the United Nations firstly in its history on 10 June 2004 has declared 2005 the World Year of Physics.

This act is clear recognition that physics, in particular, and science, in general makes important contributions to society. From electricity and transport to computers and the Internet, physics has laid the foundation for numerous transforming technologies over the past 200 years. Especially physicists are proud of their central role in science and society in the twentieth Century. The advances and breakthroughs of 20th-century physics have enriched all the sciences and opened a new era of discovery. They have touched nearly every part of our society, from health care to national security to our understanding of Earth's environment. They have led us into the information age and fuelled broad technological and economic development. The pace of discovery in physics has quickened over the past two decades. New microscopic devices are being developed with a host of potential applications, and instruments of unprecedented sensitivity and reach are being created and employed. Physics at the tiniest distances is being linked to the origin and fate of the universe itself.

The WYP2005 marks also the 100th anniversary of Albert Einstein's "miraculous year" in which he published five important papers describing ideas that have since influenced all of modern physics. These scientific papers have provided the basis for three fundamental fields in physics: the theory of relativity, quantum theory and the theory of Brownian motion. Therefore this year provides the opportunity to celebrate Einstein, his great ideas, and his influence on life in the 20th century.

Thus the WYP 2005 is a world-wide celebration of physics and its importance in our everyday lives. Physics not only plays an important role in the development of science and technology but also has a tremendous impact on our society. WYP aims to raise the world-wide awareness of physics and physical science.

However recognising the great achievements of physical sciences in the past it is more important to look to the future.

The huge technological developments of the 20th century, of course, have come with a price tag. In particular, our use of the Earth's finite resources - triggered by the insatiable demands of the world's increasing population - has escalated. Managing these resources without depleting them for good - a concept known as "sustainable development" - is one of the most urgent challenges we face today. Physics will play a crucial role in solving the global problems of the society, which are classified in four main areas:

- **Economic Development**
- **Energy production**
- **Environmental protection**
- **Public health.**

Society has other urgent needs, which modern physics is poised to address. How will we meet our energy needs as Earth's environment changes and its natural resources become depleted? Physicists' involvement in molecular biophysics, solar energy collection and conversion, or laser fusion may contribute to a solution. Health threats are likely to increase on our interconnected and highly populated planet, and rapid response to new contagions requires the development of ways to detect biomolecules remotely through advanced laser technique.

Now we live in an era of astounding technological transformation of economy in which change, not stability, has become the norm. All around us are now-familiar technologies, heir present state of development—or very existence— would have seemed extraordinary just a generation ago. In 1776 when Adam Smith published his massive four-volume study An Inquiry Into the Nature and Causes of the Wealth of Nations, he noted that the specialization of labor had vastly increased industrial productivity. He then observed that as workers become more skilled, businesses become more efficient, which leads inexorably to "the invention of a great number of machines which facilitate and abridge labour and enable one man to do the work of many". So was born the idea that „innovation" is an important ingredient in economic development. By 20th century, econometric measures of innovation revealed a clear link between industrial performance and investment in science, education and technology. As century progressed, those nations that learned to develop and exploit innovation were rapidly transformed from agrarian subsistence economies to wealthy technological states. From wireless telephones and handheld GPS units to video games, DVD, and digital television; to genetic engineering, decoding of the human genome, and combinatorial drug design; to MRIs, CT scans, laser eye surgery, and robotic hip replacement surgery; to polymeric materials for inline skates, tennis rackets, and skis; to superalloys for jet engine turbine blades; to lightweight, fuel-efficient automobiles and aircraft; to computers, the Internet, and the World Wide Web—technology is everywhere and touching all of us in ever more pervasive ways. All of this technology does not just happen. It arises from innovation based on decades of research in the underlying basic science, of which physics is a major component in essentially every case. Some of concludent illustrations of physics involvement in the economic development are related to:

- *information and communication technologies (ICT), which move from the developed world to lower cost centres of production, thus requiring local expertise;*

- *emerging field of nano-science and nanotechnology, which allow for the first time, to break free from traditional raw material-based production infrastructures and move into knowledge-based and modern economic, political and social systems;*
- *transport, where physics provides solutions to difficult problems;*
- *modern, knowledge-based agriculture and food production and a range of further areas.*

ICT has created a new way of viewing the ways in which different industrial, agricultural, and service elements link together so that more than just the economic contribution of these different growth segments can be identified. These technologies challenge us to find new ways in which human efforts can enhance institutional life and sustain technological learning in developing economies. Today's computers are doubling in performance every year or two. This will end when the ever-shrinking size of electronic components approaches the level of individual molecules and atoms. Quantum physics offers a radically different approach to information processing, whereby single atoms and photons could be the new hardware. This could lead to computers capable of solving problems that are intractable on any imaginable extension of today's computers but that are important in areas from basic science to national security. Quantum communication might provide some security against interception beyond anything possible in today's cyber infrastructure. These applications are based on the strangest and least intuitive concepts of quantum physics, such as Einstein's action-at-a-distance, which allows teleportation and the remote transfer of information without physical contact. Quantum computing is forcing us to explore both theoretical and experimental quantum mechanics at their deepest levels.

Nanotechnology is the study, design, creation, synthesis, manipulation, and application of functional materials, devices, and systems through control of matter at the atomic and molecular levels and the exploitation of novel phenomena and properties of matter at that scale. Nanotechnology can contribute new tools to address sustainable development problems, and it can strengthen the technologies already available and make them more efficient. It will coexist with rather than replace established technologies. Its impact will be felt in multiple ways, depending on how other technologies converge and align themselves around it. Nanotechnology is likely to be particularly important in the developing world as it is R.Moldova today, because it involves little labor, land, or maintenance; it is highly productive and inexpensive; and it requires only modest amounts of materials and energy.

We are now in the early stages of a second "quantum revolution" in which we can see and control tiny clusters of atoms and indeed even individual atoms. This second revolution is bringing together two central strands of the physics endeavor: atomic and condensed matter physics. The nanoworld lies in the transition region between our familiar classical world of relatively well-behaved macroscopic objects and the quantum world of atoms and molecules. These nanostructures have counterintuitive but useful optical properties that come from their subwavelength dimensions. Scientists see unique opportunities to tailor material properties for efficient optical switches, light sources, or photoelectric power generators. Negative index nanomaterials could dramatically improve optical microscopes or reduce the feature size in chip fabrication. Other applications include photonic crystals, single photon sources and detectors, environmental monitoring, and biomedical optics, with applications such as killing cancerous cells via localized optical absorption and heating.

With the needs to develop cleaner energy and mitigate the adverse effects of climate change, for example, society will increasingly depend on physics to understand and solve the problems of energy production and environmental protection. Taking clean water as an example, membranes that are made from carbon nanotubes - rolled-up 2D sheets of graphite -

can be used to block the passage of bacteria, viruses, heavy metals and other pollutants. They can therefore be used as effective filters for purifying water. Carbon nanotubes can also withstand relatively high temperatures, which means the filter could be unclogged periodically by heating it; conventional polymer-based water filters, in contrast, are destroyed if heated. Meanwhile, natural tracers such as tritium, helium-3 and carbon-14 - in conjunction with chemical and hydrological measurements - can be used to determine where ground water has come from and whether it has been contaminated with pollutants. Such information is critical for determining if the water is safe to drink. Other applications of physics include the development of recyclable polymeric nanocomposites that may replace metals and other materials that are currently used in industrial manufacturing.

Harnessing renewable energy sources through cleaner, more affordable, and more reliable technologies can prevent the dependency of developing countries on fossil fuels and avert potential energy crises and environmental degradation brought about by the depletion of oil and coal. Improved access to clean energy could play a role in improving health and increase the efficiency of agricultural production. Applications of nanotechnology such as solar cells, fuels cells, and novel hydrogen storage systems based on nanostructured materials promise to deliver clean energy solutions. Nanophotovoltaic devices, such as those based on quantum dots or ultrathin films of semiconducting polymers, can significantly reduce the costs associated with conventional solar cells. Carbon nanotubes can be used in composite film coatings for flexible solar cells. A major expense associated with hydrogen as a source of energy is its generation from water, a process that requires energy. Photo- and thermo-chemical nanocatalysts can be used to generate hydrogen from water at low costs. Electricity can also be cheaply produced using green technology from artificial systems that incorporates energy transduction proteins into an engineered matrix. Organic light-emitting devices based on semiconducting nanospheres can be developed to improve rural lighting.

Much of the improvement in human welfare over the past century can be accounted for by technological innovation in public health, nutrition, and agriculture. These improvements have reduced mortality rates and increased life expectancy. Telemedicine links, using broadband communication, could bring healthcare services to remote areas of the developing world. Novel recyclable materials could be produced by nanotechnology and self-assembly of molecules, while genetic engineering could help to develop foods and plants such as cotton that are resistant to harmful insects.

All above shortly mentioned aspects are related to “external” challenges of physics in connection with society and global problems. However, what are “internal” challenges of physics at the beginning of the new millennium in the WYP2005? What new answers do we seek? What knowledge must we obtain?

Physical community has identified, from many important and relevant issues, six broad grand challenges that succinctly describe key scientific opportunities available to physical science:

1. **Developing Quantum Technologies;**
2. **Understanding Complex Systems;**
3. **Exploring the Universe;**
4. **Unifying the Forces of Nature;**
5. **Creating New Materials and Products;**
6. **Applying Physics to Biology and Medicine.**

1. Due to all that was discovered in the 20th century about the nature of quantum physics, scientists are now at the dawn of a new kind of quantum revolution, in which *coherence* and *control* are the watchwords. The ability to manipulate individual atoms and

molecules will lead to new quantum technologies with applications ranging from the development of new materials to the analysis of the human genome. A new generation of technology will be developed with construction and operation entirely at the quantum level. Measurement instruments of extraordinary sensitivity, quantum computation, quantum cryptography, and quantum-controlled chemistry are likely possibilities. As the structures being explored for new electronic devices become smaller than the wavelength of light, one enters the realm of nanoscale physics, a field that is rapidly evolving and expanding as the size of structures decreases and the quality and complexity increase. New tools for material fabrication have now emerged that permit cutting and pasting almost on the atomic scale. The nanofabrication challenge for the future is to achieve control in all three dimensions like the layer precision of Molecular Beam Epitaxy in one dimension. Many structures in nature are well self-organized on the nanoscale. A challenge for artificial self-assembly is to reach the perfection often required for specific physical properties. A related and important new direction for the coming future is called "molecular electronics." Fundamentally, quantum mechanics is a theory of information. A realistic quantum computer must be based on switches built out of electrons and nuclei of individual atoms, or nanoscopic condensed matter systems.

2. The rapid advances of massively parallel computing, coupled with equally impressive developments in theoretical analysis, have generated an extraordinary growth in our ability to model and predict complex and nonlinear phenomena and to visualize the results. Problems that may soon be rendered tractable include the strong nuclear force, turbulence and other nonlinear phenomena in fluids and plasmas, the origin of large-scale structure in the universe, and a variety of quantum many-body challenges in condensed-matter, nuclear, atomic, and biological systems. In the study of complex systems, physicists are expanding the boundaries of their discipline: They are joining forces with biologists to understand life, with geologists to explore Earth and the planets, and with engineers to study crack propagation. Much progress is being made in applying the quantitative methods and modeling techniques of physics to complex systems, and instruments developed by physicists are being used to better measure the behavior of those systems.

3. The universe is still a mysterious place. The universe itself is now a laboratory for the exploration of fundamental physics. New instruments through which stars, galaxies, dark matter, and the Big Bang can be studied in unprecedented detail will revolutionize our understanding of the universe, its origin, and its destiny. New measurements will test the foundations of cosmology and help determine the nature of dark matter and dark energy, which make up 95 percent of the mass-energy of the universe. Questions such as the origin of the chemical elements and the nature of extremely energetic cosmic accelerators will be understood more deeply.

4. Determining of the basic constituents of matter is an important step toward an historic goal: the discovery of a unified theoretical description of all the fundamental forces of nature—the strong nuclear force, the electroweak forces, and gravity. This challenge was a great dream of A.Einstein. The most promising and exciting framework for unifying gravity with the other forces is string theory, which proposes that all elementary particles behave like strings at very tiny distances.

5. The discovery of materials such as high-temperature superconductors and new crystalline structures has stimulated new theoretical understanding and led to applications in technology. Several themes and challenges are apparent—the synthesis, processing, and understanding of complex materials composed of more and more elements; the role of molecular geometry and motion in only one or two dimensions; the incorporation of new

materials and structures in existing technologies; the development of new techniques for material synthesis. The ability to create new materials and structures is inextricably linked to advances in the understanding of fundamental phenomena in material physics. These advances, along with improvements in synthesis and processing, have led to an astonishing array of new materials with unexpected properties and to dramatic improvements in the properties of established materials. New materials allow entirely new device concepts to be realized or lead to a dramatic change in scale, such as single-molecule wires made of carbon nanotubes.

6. Like all aspects of the modern world, medicine has been transformed by discoveries in physics during the past century. Modern medicine is unthinkable without modern chemistry, and modern chemistry could never have existed without the fundamental understanding of atoms and molecules provided by the revolution in physics that started just about 100 years ago. The basis for medical practice resides in an understanding of how the body functions. Physics has contributed to this knowledge in essential ways through biophysical research and through the development of enabling technologies for the biological sciences. At the level of molecules, structure and function are inseparable. Understanding the structure of complex biological molecules is also the key to developing new pharmaceuticals by an approach that is more rational than the hit-and-miss approach of the past.

For today global society challenges of physics is characteristics its covering both world and inside country levels. Physical investigations today are structured in international research network. Therefore, the linkages of "external" challenges for physics to the national needs of R.Moldova as well as the linkages of "internal" challenges of physics to national research and development goals are evident. In the context of this short review physics should be a priority for science of Moldova. The WYP2002 is not only an opportunity for us to join the International community for physics celebration, but it is an opportunity to raise public awareness of physics and physical science in our developing country, to attract a new generation of scientists and to find the linkages of physical researches to the needs of our country. National priorities of R.Moldova are stipulated in different programs and strategies of development such as Strategy of poverty eradication and economic growth. Physics can contribute to these national priorities being involved in:

- *Advancing fundamental investigations to develop scientific platform of qualitative economic growth and to improve the quality of life.*
- *Enabling technological innovations that spur economic competitiveness and job growth.*
- *Providing knowledge and tools to assure energetic and informational development of the country.*
- *Contributing to the development of therapies and diagnostic medical systems that enhance the health of the nation's people.*
- *Educating in science, mathematics, and engineering to ensure a scientifically literate population and qualified technical personnel who can meet national needs,*
- *Enhancing our ability to understand and respond to global and local environmental issues.*
- *Participating in International and European partnerships that foster the advancement of scientific frontiers and accelerate the progress of science across borders.*
- *Contributing to the mission adviser goals of government and departments.*

In order to allow physics to contribute strongly to areas of national need, the government and the physics community should develop and implement a strategy for long-term investment in basic physics research. Key considerations in this process should include the overall level of innovative infrastructure necessary to assure economic growth driven by new physics-based technologies**.**

An essential part of maintaining the physics leadership in the science of R.Moldova and international competitiveness as well as deeper involving in solution of society needs is to train and to equip the next generation of physical scientists. Physics and other related departments
should review and revise their curricula to ensure that they are engaging and effective for a wide range of students and that they make connections to other important areas of science and technology.