



Physics in Our Lives

Editors

Dr. Hameed A. Khan
Prof. Dr. M.M. Qurashi
Engr. Tajammul Hussain
Mr. Irfan Hayee

July 2005



**Commission on Science and Technology for
Sustainable Development in the South**

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COMSATS' Series of Publications on Science and Technology

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COMSATS Headquarters
4th Floor, Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad.
Ph: (+ 92-51) 9214515-7, Fax: (+ 92-51) 9216539
URL: <http://www.comsats.org.pk>, email: comsats@comsats.org.pk

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FOREWORD

Throughout world history, different civilizations have attempted to better their living through science and technology. Science and technology have had a fundamental impact on the way people live today, from the early use of the first metal-tools by Neolithic people, to children receiving vaccination-shots today. Different eras in history, like the period of Neolithic Revolution; eras of Classic Civilizations such as, the Greeks, Romans, and Chinese; Renaissance Europe; and the Golden Age of Islam, have been marked by important discoveries in science.

Ever since Galileo, physicists have been pioneers in research and their contributions in this field have ameliorated our way of living. Research in Physics allows us to look forward to a future that holds even more exhilarating breakthroughs and advances. The studies of physicists range from the tiniest particles of matter, to the largest objects in the universe. They have made possible the luxuries and conveniences inside our houses - such as energy-efficient heating-systems, personal computers and CD players. Much of the technological equipment and techniques used by other scientists were also originally developed by physicists, such as, X-rays, MRIs and other medical instruments, to safely study the human body, diagnose and treat diseases. From saving lives to saving our environment, and to promoting knowledge in other areas of science, the contributions of physicists have always been extraordinary.

Keeping in view the importance of Physics in the modern society and in order to celebrate the 100th anniversary of the most famous five papers published by Albert Einstein, the year, 2005, has been declared the 'World Year of Physics' (WYP) by the General Assembly of the UNO (United Nations Organization). WYP-2005 aims to facilitate the sharing of visions and convictions about physics amongst international community of physicists and the public.

In order to commemorate WYP-2005, COMSATS organized a two-day International Seminar on "Physics in Our Lives", on February 23-24, 2005, at Islamabad. This seminar was organized in collaboration with Pakistan Atomic Energy Commission (PAEC) and the National Centre for Physics (NCP), Quaid-i-Azam University, Islamabad. The basic purpose of conducting this Seminar was to bring to light the contributions that physicists have been making and can further make in the future; to improve the quality of life and; to provide a forum for interchange of ideas, between academia, research institutes and the industrial sector, pertaining to Physics and its role in society. Another objective of holding this Seminar was to facilitate the public awareness of physics, its economic necessity, its cultural contributions and its educational importance.

There were a total of 29 speakers in the Seminar who made presentations in five Technical Sessions, of which four were foreign experts representing countries of

Switzerland, Syria, Egypt and Sudan. Other participants included eminent physicists, heads of S&T institutions, scholars and students from various academic and research institutions.

The book contains eighteen papers from the afore-mentioned Seminar on 'Physics in Our Lives', and has been segmented into two broader categories, i.e., 'General Perspective' and 'Contributions of Physics to Specific Fields'. The papers in the first part take stock of the historic evolution of physics, while in the second part field-specific contributions of physics are detailed.

I would like to express my gratitude to Mr. Parvez Butt, Chairman, Pakistan Atomic Energy Commission (PAEC) and Prof. Dr. Riazuddin, Director General, National Centre for Physics (NCP) for their ardent cooperation and support for organizing this conference. Here, I would like to acknowledge the efforts of all the speakers and physicists and my earnest praise also for Dr. M.M. Qurashi, Ms. Noshin Masud, Ms. Nageena Safdar, Mr. Irfan Hayee and Mr. Imran Chaudhry from COMSATS, whose devotion made possible the publication of this book.

(Dr. Hameed Ahmed Khan, H.I., S.I.)
Executive Director

CULTURAL AND SOCIAL ASPECTS OF SCIENCE

Fayyazuddin
*National Centre for Physics, Quaid-i-Azam University
Islamabad, Pakistan*

ABSTRACT

The impact of Physics on human culture, in particular on human intellect and the role of physics in social evolution of human society is described and discussed in the paper.

INTRODUCTION

“The knowable world is incomplete if seen from any one point of view, incoherent if seen from all points of view at once, and empty if seen from no where in particular.”

Richard A. Shwder

“Why do Men Barbecue? Recipes for cultural psychology”, Dr. Shwder being a social anthropologist is talking of interactions of various cultures in understanding the world. Science is also a part of human culture. How do we define culture? One may say, anything which enriches human-civilization, entirely because of its intrinsic value falls in the domain of culture. The essence of culture is in those things, which from purely utilitarian point of view may be useless. Philosophy: art; literature and music; mathematics and basic sciences are all part of cultural heritage. They generate social capital. Social capital creates an environment for an enlightened, tolerant society which values human life and rule of law. It keeps darkness in human soul in a dormant state. There is another aspect of culture, which is concerned with cultural traits of a society and its social evolution. Science has made tremendous contributions in the social evolution of mankind. Oscar Wilde once said, “a cynic knows the price of everything and the value of nothing. A bigot is a chronic cynic”.

In a bigoted society, culture has no value and is least appreciated. In the Science-Year 2005, two plays ‘Galileo’ by Bartolet Brechet and ‘Copenhagen’ by Michael Frayn, will be staged in the west.

Galileo has a very special place in the development of physics. He is regarded as ‘father of modern science’. He challenged the authority of Aristotle. By performing a simple experiment by dropping two stones, he proved Aristotle wrong. He discovered ‘law of falling bodies’ (Terrestrial Gravity). He, thus, re-initiated the scientific method viz deduction of scientific laws from observations and experiments. He challenged the authority of Church and came decisively in favor of heliocentric (Copernican) system in which the Sun is at the centre of solar system and the planets, including the Earth revolve around it. This brought him in conflict with the Church, which regarded the Earth as the centre of the Universe (Ptolemaic scheme), in which Earth remains

stationary at centre, whereas planets including the Sun and moon revolve around it. Moreover, he came to the conclusion that there is no preferred frame of reference; the laws of Physics are invariant, i.e., have the same form in all inertial frames. To save his skin, he renounced his theory, but when he came out of prison, he said, “but it still moves”. Galileo became victim of bigotry in Italy. The significance of Galileo’s work is that he challenged the ancient beliefs, intolerance and suppressive social order.

THREE ASPECTS OF SCIENCE

Berchet wrote play about Galileo. The paper describes one scene from this play to illustrate three aspects of science and how they are appreciated (Occasion: Invention of telescope by Galileo), Curator (in his best chamber – of – commerce manner) Gentlemen: Our Republic is to be congratulated not only because this new acquisition will be one more feather in the cap of Venetion culture (Polite applause), not only because our own Mr. Galilei has generously handed this fresh product of his teeming brain entirely over to you to manufacture as many of these salable articles as you please – (considerable applause) – but, Gentleman of the Senate, has it occurred to you that – with the help of this remarkable new instrument – the battle fleet of the enemy will be visible to us full two hours before we are visible to him? (tremendous applause).

In this respect we are not behind, but a step ahead. Every thing is security-driven. It is strange but true that the ugly aspect of science is appreciated more reaching “*A science is said to be useful if its development tends to accentuate the existing inequalities in the distributions of wealth or more directly promotes the destruction of human life.*”

G. H. Hardy; An apology of Mathematician with this prelude,

EVOLUTION OF PHYSICS

The paper now discusses evolution of Physics and its impact on society. The Greeks made remarkable contributions to human-civilization. They invented, philosophy, mathematics and science: They introduced the Deductive-method. From axioms, which they regarded “as a priori”, they deduced results in a self-consistent manner. Euclidean geometry is one example of mathematics, which they invented. For them, pure thought was much superior than the work with hands or experimentation.

The Greeks also made remarkable contributions to Astronomy. Aristotle argued that the orbit of a planet must be a circle, because the circle is a perfect curve. Between ancient and modern European civilization, the dark ages intervened. Muslims and Byzantines preserved and unproved the apparatus of civilization. From the 12th century to 17th century, Ibn-Sina’s treatise was used as a guide to medicine. Ibn-Rushd was more important to Christians than in Muslim philosophy.

From arithmetic’s (numbers), which originated in India, a transition to algebra had been made in the Muslim era (Khawarizmi, Al Baruni and Omar Khyam). All these men were dead end for Muslim civilization, but for Christian civilization in Europe,

they were a beginning. In the West, the access to Greek knowledge came through the Muslims. Although Muslims were better experimentalists than Greeks, they did not go much beyond observations.

In general, they did not deduce scientific principles from observations. At the most, they deduced empirical laws from them. They were more interested in practical applications, rather than building a scientific edifice. To build a scientific edifice, it is essential to go beyond the existing thought. The ruling-class was not prepared to tolerate any thought, which would have initiated departure from the orthodoxy prevalent at that time.

Europeans also passed through a similar period, but they came out of it by evolving into liberal democracies. Bertrand Russell has called the 17th century the century of science.

Not only were the foundation of mechanics and astronomy laid in this century (Copernicus, Galileo, Kepler & Newton), but some of the tools necessary for making the scientific observations were invented, e.g., Compound microscope (1590), Telescope (1608), Air pump, improved clocks, thermometer and barometer.

Remarkable progress was made in mathematics, e.g., Napier logarithm (1614), Differential and Integral calculus (Newton and Leibniz), Coordinate Geometry (Descartes). These discoveries in mathematics laid the foundations of higher mathematics in later years. It is remarkable that these discoveries were made by persons who were also men of faith: they never believed that their discoveries were in conflict with their religious beliefs.

Nevertheless, their discoveries implicitly implied that science and religion should not be mingled with each other. Their discoveries laid the foundation of a new concept that: natural phenomena can be understood by observation and rational thinking, without invoking the divine will. Magic and superstition thus became things of the past.

There is no space for an authority in science, all laws deduced from observations are tentatively subject to modification or change with new data. Theories are accepted by consensus. This is what Neils Bohr called 'a republic of science'. It gave a new concept of man's place in the universe. It was realized that inequalities between human-beings are products of circumstances. The circumstances can be changed through education, hence the importance of education.

PHYSICS IN THE 19th AND 20th CENTURIES

The industrial revolution began at the end of eighteenth century, with the invention of steam-engine. The industrial revolution preceded the science of thermodynamics which was developed in the nineteenth century. Most of the concepts beyond

mechanics were developed in the 19th Century.

The 'First Law of Thermodynamics' (1830-1850), was an extension of Law of Conservation of Energy for purely mechanical systems. Clausius in 1850 (based on Carnot's work) stated the Second Law of Thermodynamics "Heat cannot go from colder to warmer body with out some accompanying change". Entropy was also introduced by Clausius in 1865. He then stated both the laws:

"The energy of the world is constant and its entropy strives towards a maximum".

Statistical interpretation of the Second Law was one of the great advances of the 19th century. In particular, Boltzman stated second law in precise form:

"For a time-reversal invariant dynamics (Newtonian Mechanics), macroscopic irreversibility is due to the fact that in the over whelming majority of cases, a physical system evolves from an initial state to a final state which is almost never less probable.

In the approach to equilibrium, the increase in entropy is not the actual but the most probable course of events."

Increase of entropy is linked to increase of disorder, which is irreversible. The irreversibility of evolution in biosphere is an expression of the second law. A simple mutation, such as, substitution of one letter in DNA-code for another, is reversible. However, for an appreciable evolution, a great many mutations successively accumulated at random; because of independent events that produce them, is irreversible. Also in 19th century two great conceptual revolutions, associated with Darwin (theory of evolution) and Maxwell (unification of electricity and magnetism) took place.

Electric environment is man-made. In nature, electricity is seen in lightening. Certain stones called magnetite exhibit magnetic properties. Nothing seems to be common between them. Basic laws governing electromagnetic phenomena were formulated (Coulomb, Ampere, Faraday) in 19th century. Faraday's Law of Electromagnetic Induction is a discovery of great importance, as thus made it possible to generate electricity directly from mechanical energy. Electric energy has a great advantage that it can be easily transported to homes and is used in numerous ways. We live today in an environment created by electricity.

The idea of electric and magnetic fields introduced by Faraday and Maxwell had a profound impact on the development of physics. Maxwell after modifying 'Ampere's Law' with the introduction of displacement-current, wrote the four differential equations, which show a symmetry between electric and magnetic fields. These equations encompass the whole range of electromagnetic phenomena.

A consequence of Maxwell's equations is that electric and magnetic fields propagate

through space as waves, with the speed of light. Hertz experimentally demonstrated the existence of electromagnetic waves. His work gave stimulus for practical applications of Maxwell's equations. This is how electronic communication was born. One of the far-reaching impacts of Maxwell's equations is to give birth to a powerful tool in the form of electronic media, to shape the opinion of people for political aims or ideological indoctrination, or for marketing of product, especially by multinationals.

Never in the history of physics, did such an abrupt and unanticipated transition take place as during the decade 1895 - 1905. Roentgens discovered X-rays in 1895. Radioactivity was discovered by Becquerel in 1896. In 1897, J.J. Thomson discovered the electron - the first elementary particle. On December 14, 1900, Max Planck put forward the idea of the quantum. The emission and absorption of radiation from an atom take place in discrete amounts- that he latter called "quanta".

The discovery of atomic nucleus was announced by Rutherford in 1911. Neutron was discovered by Chadwick in 1932. Radioactivity is the only nuclear phenomenon, which is found on the Earth. Nuclear environment exists in star. With the development of nuclear reactors and nuclear weapons, an environment is created by human-beings, which is natural in stars.

The development of nuclear energy and nuclear weapons of mass-destruction have left a strong mark on modern society.

The birth of 'quantum theory' (1900) and 'relativity theory' (1905) marked the beginning of an era, in which the foundation of physical theory needed revision. The Transition from 'Newtonian mechanics' to 'special theory' and 'general theory of relativity' was smooth. Maxwell's equations are consistent with the theory of relativity.

But Newtonian mechanics is not compatible with the special theory of relativity; when it is made compatible with the special theory, one gets Einstein's famous equation $E=mc^2$. Another consequence of special theory was time-dilation, i.e., moving clocks are slowed down. The general theory of relativity is concerned with gravity. Einstein noted that gravity is always attractive, unlike electricity, where an electrically neutral system can exist. But gravity can never be switched off. So it is a property of space-time; due to existence of matter, the space-time becomes curved. He had the mathematical apparatus available in the form of Riemannian geometry to formulate his theory of gravity.

But the transition to 'quantum theory' was not smooth. It was like a revolution. As in a revolution, there is a period of turmoil and it takes sometime to restore a new order; this was also the case for 'quantum revolution'. New order was established by Heisenberg with his discovery of 'Matrix Mechanics' in 1925, and by Schrödinger by his wave-mechanics, a little bit latter. By unifying 'special theory of relativity' with 'quantum mechanics', Dirac predicted the existence of anti-matter. Determinism of classical mechanics is replaced by uncertainty principle, i.e., When events are

examined closely, a certain measure of uncertainty prevails; cause and effect become disconnected; causal relations hold for probabilities; waves are particles and particles are waves; matter & anti-matter are created and destroyed (vacuum polarization); chance guides what happens.

The unification of terrestrial and celestial gravity by Newton; the unification of electricity and magnetism by Maxwell; the unification of 'special theory of relativity' with 'quantum mechanics' by Dirac were the hallmark of physics. In the same context, the unification of electromagnetism with radioactivity was achieved by Glashow, Salam and Weinberg in late 1960's, with prediction of a new kind of weak current, called the 'neutral weak current', subsequently discovered experimentally in 1978. This unification also predicted the existence of massive weak vector bosons called W^+ , Z^0 which mediate the weak force (responsible for radioactivity). W and Z bosons are partners of photon (quantum of electromagnetic field, which is mass-less and mediates the electromagnetic force).

Weak bosons were experimentally discovered in early 1980, at CERN, Geneva. C.P. Snow in his book "Two Cultures" divides the industrial revolution into three phases. The first phase, which began with the invention of steam-engine at the end of 18th Century, was mainly created by handy men, as C.P. Snow calls them. In the second phase of industrial revolution, chemistry played a major role. Giant chemical companies were established in Europe and USA. In the third phase of industrial revolution, atomic particles like electrons, neutrons, nuclei and atoms played a crucial role. This revolution is based on physics of the 20th Century. The birth of 'quantum theory', in the 20th century, had a tremendous impact on future development.

It is hard to imagine that without 'quantum mechanics', transistors, computer-chips and lasers could have been invented. According to Leon Lederman (Former Director of Fermi Lab) "If everything we understand about the atom stopped working, the GNP would go to zero".

Physicist Freeman Dyson calls the fourth phase of revolution 'tool-driven revolution'. Scientists develop new tools and computer-software. The craftsmanship used in their tools may initiate new technologies. Two examples: X-rays and nuclear-magnetic resonance Computed Axial Tomography (CAT), Magnetic- Resonance Imaging (MRI) scanning-technology revolutionized diagnostic techniques in medicine. It may also lead to some landmark discoveries in basic sciences. A prime example is the use of X-rays crystallography to study biological molecules.

Such a study led Crick and Watson to unfold the structure of DNA – the genetic code- perhaps the greatest discovery in biology after Darwin's work. The subsequent developments in DNA-testing, genetic engineering and bioinformatics had made an enormous impact on human society. Another example is the World-Wide Web (www), developed at CERN, for basic research, which has revolutionized the information-technology.

On the other hand, tremendous progress in space-technology has been used to put the probe in outer space, to study the structure of universe.

The paper concludes that science has made such an enormous impact on the human-intellect that it drastically changed human-living. Scientific discoveries are beautiful, but scientific inventions can be good or bad.

IMPACT OF S&T ON HUMAN SOCIETIES

There is no doubt that science and technology have made the remarkable contributions to raise the standard of living and to improve the quality of life. But it has also increased the gap between the rich and the poor. While, on one hand, tremendous progress in the medical sciences, immunology and drugs has alleviated the human-sufferings and has increased the span of life; yet, on the other hand, it has increased the destructive power of man in the form of weapons of mass destruction.

Excessive use of technology has increased industrial pollution several fold. This poses a long-term threat to natural environment, which would effect the quality of life. Science by itself does not guarantee the genuine progress of society, though it is one of the ingredient for progress. Social capital is needed for synthesis of society: to narrow the gap between the rich and the poor.

CONCLUSIONS

It took millions of years for biological evolution through natural selection. Evolution in the biosphere is necessarily an irreversible process. Time-scale for social evolution is much smaller – it took less than 10,000 years for an appreciable social evolution. Is social evolution reversible? We do not have a second law for the social sphere, although social structure is also complex. History tells us that any great civilization, which has decayed, has never come back in its original form. Those who dream to regain lost glory and do not want to go above the past are defying this history.

P. R. Mooney in an article (in the Development Dialogue 1999, published by Dag Hammerskjold Foundation) has expressed the viewpoint that 21st century will be the ETC century. ETC stands for 'Erosion, Technological Transformation and Corporate Concentration'.

Erosion includes not only genetic erosion and erosion of species, soils, and the atmosphere, but also the erosion of knowledge and the global erosion of equitable relations. Technology means new technologies, such as biotechnology, nanotechnology, informatics and neuroscience. Concentration describes the re-organization of economic power into the hands of high-tech global oligopolies. The ETC combination could lead to a world of cyber-cabbages and Nano-kings.

American writer O. Henry described Central American at the dawn of 20th century – a

'banana republic'. Were he alive, O. Henry might well call the coming world-order, 'the Binano republic.

Mooney's predictions are based on linear extrapolation from 20th century to 21st century. But for a complex system, linear extrapolation may not hold. However, the recent trends indicate that some of his observations may soon come through.

"The only sensible thing to say about human nature is that it is "in" that nature to construct its own history." (Rose, Lewonton and Kamin, "Not in our Genes").

The Future will tell how human-beings construct their own history.

EVOLUTION AND IMPACT OF PHYSICS ON OUR LIVES

Hameed Ahmed Khan
Executive Director
COMSATS Headquarters, Islamabad, Pakistan

ABSTRACT

Physics is the most basic of all sciences and its importance in our everyday life cannot be emphasized enough. However, to capture the true picture of physics' contribution to improving mankind's quality of life, one must take a journey back in time and follow the road to the evolution of science and technology in general and physics in particular.

This paper gives an unbiased account of the series of events that led to the evolution and development of physics as we know it today. Starting from the Big-Bang, this paper journeys through various eras during which science developed and thrived. Major contributions by eminent scientists in this connection are highlighted. The fruits of S&T development especially in the field of physics, and its impact on our day-to-day life are also discussed in detail, underlining the involvement of physics in our personal as well as professional lives. Finally, the author details the role of physics in the 21st century and leaves its readers with a list of open-ended questions to further generate knowledge in the field of physics.

“The whole of science is nothing more than a refinement of everyday thinking”
Albert Einstein

1. WHAT IS PHYSICS AND WHAT MAKES A PERSON A PHYSICIST?

The earlier explanations of physical phenomena were ascribed to mythical gods who played key-roles in creating and preserving the world. These myths, elaborated upon and added to by the men who told and retold them from generation to generation, reflected man's continuing need for support. His sentimental responses to his environment largely shaped these myths. The world, as early man knew it, was vastly different from the world we know today, even though the rivers, the oceans, the mountains, the sun and the moon, the planets and stars are all essentially the same. The change has come in man himself. As he changes, he must describe his world differently. To a person born into an age of rapidly evolving technology, physics tends to be associated with the useful devices like, T.Vs, refrigerators, airplanes, ships, rails, rockets, missiles, bombs, electronic equipments used in medical centers, machines in factories. Computers, etc. But in a more complete sense, physics is an intellectual activity rather than being a purely technological one. Physics has explained the

energy-mass conversion, time-space relationship, order and disorder, self-organization, chaos, uncertainty, wave-particle duality, etc.

Physics may be thought of as knowledge that has been accumulated from observations of physical phenomena, systematized, and formulated with reference to general statements in the form of 'theories' or 'laws', which provide a grasp or a sense of greater understanding of the world in which we live.

Science (or Physics) looks into the material world objectively. What one person (a scientist) observes or predicts theoretically can be verified by the others, provided the required conditions can be achieved. To elaborate our point, we can just quote one particular example. Different poets will describe the moon in different ways because of subjective vision, while all the physicists will describe the moon in the same way. First-hand observation and personal experience with phenomena are essential elements in sciences.

When we start learning physics, we begin with motion. Velocity, acceleration, force, mass, energy, momentum—these are some of the concepts that are found in an elementary physics course. The principles developed can apply to the motion of anything—planets, electrons, athletes, owls, glaciers...Physics is really the study of everything in the universe.

What Makes a Person a Physicist ?

In principle everybody who asks questions about the physical things and physical phenomena around him is a physicist. Yes a child is also a physicist. Then why only a few persons are called physicists? The answer is very simple but important. A physicist is not only a person who asks questions momentarily and then forgets. A physicist is a person who remains in search of answers to his questions. Physicist speculates, makes hypotheses, and carries out experiments, form theories and laws about the working of nature. A physicist also remains unsatisfied throughout the life due to his curiosity and quest for knowledge.

Physics is an organized way of conversing with nature. Physicists ask questions; nature responds. For many questions, the answers are almost predictable, but when the question is a particularly good one, the answer can be unexpected and gives us new knowledge of the way the world works. These are the moments physicists live for.

To a physicist, the term “absolute truth” is also a relative term. From a physicist's point-of-view, we are absolutely certain of nothing in the real world. There is talk of a “final” theory, a theory of everything. (Right now, we have sort of a patchwork. Quantum mechanics and gravitation are disconnected, for example.) It may happen that we achieve a single theory for all of physics, but we can never be 100% certain that it is exactly correct. It could happen that a final theory will be developed, but we won't know for certain that it is final! When people talk about a final theory, they are not

saying that we will know everything. It would in fact be a new beginning in the search for knowledge.

The fundamental ideas of physics underlie all basic sciences: astronomy, biology, chemistry, and geology. Physics also is essential to the applied science and engineering that has taken our world from the horse and the buggy to the supersonic jet, from the candle to the laser, from the pony express to the fax, from the beads of an abacus to the chips of a computer.

Branches of Physics

Since physics is the study of whole universe, therefore, it has been divided into several branches. If we look deeper and carefully then even chemistry and biology would be the branches of physics. But for the sake of clarity and simplicity we have to classify the study of nature into several subjects. Each one of these subjects has the basis on the principles of physics. For example, a very simple view about chemistry can be that it deals mainly with those reactions among elements and compounds, which are due to the electronic structures of atoms and molecules. Similarly biology is the study of living things. But the behavior, development and evolution of living things are based on laws of physics. For example our brain sends electronic signals to different organs of the body, which work for us. At present, we shall assume physics to be a subject different from chemistry, biology, botany, etc. To be specific, we may define physics as the subject that deals with the fundamental forces of nature, and the constituents of matter all over universe. There are several branches of physics, which include:

- Astronomy, Atomic Physics, Cosmology, Dynamics, Electricity, Electrodynamics, Field Theory, High Energy Physics (also known as Particle Physics), Hydrostatics / Hydrodynamics, Magnetism, Mechanics, Nuclear Physics, Optics, Particle Physics (also known as High Energy Physics), Plasma Physics, Quantum Electrodynamics (also known as Quantum Theory of Light or Quantum Theory of Radiation), Quantum Mechanics, Solid State Physics, Statics, Surface Physics, Thermodynamics, Wave Mechanics etc.

If we go back in time, the evolution of physics is inherently driven by the quest of mankind to learn and to know, so it is, a priori, without any other names (business, communications, energy, defense, etc). The next part of this paper would shed light on the evolution of physics.

2. EVOLUTION OF PHYSICS: HISTORIC PERSPECTIVE

The modern era is characterized by innovation and progress in virtually all walks of life. Over time, almost all sectors of society have experienced dynamic advancements, which have allowed mankind to devise ways and means to improve and uplift the quality of its life. Without a doubt, the modernization that we experience today did not occur over a period of mere years, but evolved over a timeframe of centuries.

Nevertheless, one can safely state that science and technology have been the forerunners of most modern revolutionary achievements, and it is only due to the progress in these fields that one experiences a complete transformation from the stone-age to the current age, distinguished by comfort and sophistication.

2.1 The Greek Period

Early traces of the evolution of science can be dated back to the 7th century BC-Greek era; however, those of technology are difficult to identify. It is often said that technology came before science, because mankind in its primitive ways pursued methods of repetitive hit and trial until a way was found to satisfy the requisite need. The mother of all inventions, need, led man to do technology long before he could or would do science. It is for this reason that some historians and technologists go to the extent of stating that the wheel, which is considered to be the invention that fueled the S&T evolution, was invented by technology and not science!

So, what are the historical patterns that led to the evolution of science, as we know it today? History considers earlier scientists before the Greeks to be mostly philosophers than scientists. It is the Greek era which saw some scientific progress and advancement. The contributions of Pythagoras, Plato, Aristotle and Archimedes, in the fields of astronomy and mathematics during this period, laid the foundations of developing science, especially physics in the future. It is said that Aristotle, Euclid and Ptolemy were the first three great synthesizers of science, who summarized

Table - 1: Questions and Answers at an Ancient Symposium

Question (King of Egypt)	Answers (King of Ethiopia)	Answers (Thales of Greece)
Τίπρεσβυτατον; What is the oldest thing?	Χρονοζ Time	Θεος God
Τμεγιστον What is greatest?	Κοσμοζ The Universe	Χωρος Space
Τικαλλιστον, What is most beautiful?	Φωζ Light	Κοσμος The universe
Τσοφοτατον What is wisest?	Αληθεια Truth	Χρονοζ Time
Τκοινοτατον What is most common?	θανατοζ Death	Ελπιζ Hope
Τιωφελιμωτατον; What is most helpful?	θεοζ God	Αρετη Virtue
Τβλαβερωτατον; What is most harmful?	Δαιμων Demon (An evil spirit)	Κακια Vice
Τι ισχυροτατον; What is strongest?	Τυχη Luck (Fortune)	Αναγκη Necessity
Τραστον; What is easiest?	Ηδυ Pleasure	Φυσικον The natural

respectively, Greece's contributions to general science, mathematics and astronomy. Aristotle, who was the tutor of Alexander, later became his scientific advisor, claiming the position of first scientific advisor in history. History also records the events of mankind's first scientific symposium, which was held in Corinth, Greece, during the 6th century BC. The agenda of the symposium was to answer the questions of the King of Egypt, Amasis, who posed these questions to both Greece and Ethiopia. The King of Ethiopia and Thales of Miletus answered in response (Table-1) detailing not only the flavor of scientific philosophy outlook maintained by each culture during those times, but also the difference of the nature of scientific inquiry then, as compared to today.

2.2 Romans and Chinese Period

After the Greeks, history experienced the era of the Romans, who were more focused on technology than science and, therefore, this period experienced a little progress in the realms of science itself. During the period of 'After Jesus', the Chinese made noteworthy contributions to science and technology (papermaking, gunpowder), and then came the era of the Muslims.

2.3 Muslim Period

The Muslims helped spreading the influence of science from the Mediterranean eastward into Asia, where it picked up contributions from the Chinese and the Hindus, and westward as far as Spain, where Islamic culture flourished in Córdoba, Toledo, and other cities. Though little specific advances was made in the realms of physics, the Muslims ensured preservation of Greek science and kept it alive during this period.

The much preserved and patronized science kept by the Muslim world made possible the revival of learning in the West, beginning in the 12th and 13th century. During this period, the Muslims experienced their downfall, not only in terms of their dominance in the world, but also in terms of their dominance in science. The Mongols destroyed Baghdad, which was one of the centres of Muslim scientific literature and civilization. Though the Turks continued to patronize science, much of the libraries and books preserved by the Muslim world no longer existed. In the year 1453, Istanbul also fell to the Turks. During this period, the intellectual community of the Muslims (especially those who spoke Latin) fled to Western Europe, more specifically Italy and then on to Greece. With their comfort in communication, they helped spread scientific knowledge in European languages across the western part of the continent.

Some of the books of Muslim scholars and scientists that were even translated into Latin and other European languages are listed in the Table-2.

2.4 Renaissance

During the dark and middle ages of Europe, the Church was in control of the State, and religion guided the society to abide and follow what was divine decree without

questioning. As the norms of these ages promoted nothing but blind following, the culture of science in Europe could not develop, as science dwells purely on query. During the period of renaissance, the control of the church weakened and people started questioning religious and societal beliefs. In this environment, scientific queries were also re-generated, which marked the beginning of an era of progress and development in science and its realms.

The period of renaissance also experienced a strange phenomenon, called 'Black Death'. This Black Death was a fatal disease that spread unchecked in much of Europe killing majority of the population, especially the labor class. Given this scenario, an impression arose in Europe to find an alternative to dispensable labor. This is how the era of the machines began and the reign of industrialization originated.

Table - 2: Translations of Muslim Scientists' Books into Latin and other European Languages

NAME	LATIN / ENGLISH / FRENCH / GERMAN TRANSLATION
Jabir Ibn Haiyan (Geber)	The Book of the Composition of Alchemy, Book of Kingdom, Book of the Balances, Book of Eastern Mercury, Sum of Perfection (all translated by Berthelot).
Al-Battani (Albategnius)	De Scientia Stellarum – De Numeris Stellarum et motibus (12th cent.), Al-Zij (Rome, 1899).
Al-Farghani (Al-Fraganus)	Scientia Stellarum, Jawami "The Elements" (Latin 1170-1187; Hebrew 1590; Latin 1669)
Al-Razi (Rhazes)	Continens (1279), Liber Almansoris (1480s, several editions ending in 1890), Nonus Almansuri, Liber Experimentorum, Al-Judari wa al-Hasabah (London, 1848).
Al-Masu'di	Meadows of Gold and Mines of Precious Stones (London, 1841)
Ali Ibn al-Abbas (Haly Abbas)	Liber Regius (12th cent.)
Al-Zahravi (Albucasis)	Surgical Part of Al-Tasrif li man Ajazaan al-Taalif (Venice 1497, Basle 1541, Oxford 1778)
Al-Haitham (Alhazen)	Opticae Thesaurus (12th cent., also in Hebrew)
Al-Biruni	Al-Biruni's India (London, 1914), Kitab al-Tafhim (Luzac, 1934), Book on Precious Stones (1941), Parts of Kitab al-Saydan (1945)
Ibn Sina (Avicenna)	Canon (1170-87), Sanatio (12th cent.), "A Treatise on the Canons of Medicine of Avicenna (1930), Book of Healing.
Al-Zarqali (Arzachel)	Toledan Tables (12th cent.)
Omar Al-Khayyam	Maqalat fi al-Jabr wa al-Muqabila, Rubaiyat (Quatrains, 1859, Tr. Fitzgerald)

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Ibn Zuhr (Avenzoar)	Kitab al-Taisir fi al-Mudawat wa al-Tadbir, Kitab al-Iqtisad fi Islah Al-Anfus wa al-Ajsad, Kitab al-Aghziya (12-13 th. Cent.).
Al-Idrisi (Dreses)	Al-Kitab al-Rujari (Roger's Book, 12th cent.), another in Latin (Rome, 1619, published using only Translator's name), Nuzhat al-Mustaq fi Ikhtiraq al-Afaq
Ibn Rushd (Averroes)	Colliget (13th Cent.), Almagest (1231 tr. Into Hebrew),.
Nasir Al-Din Al-Tusi	Figura Cata (14th cent.)
Al-Fida (Abdulfeda)	Geographie d'Aboudfeda (Paris, 1848)
Ibn Khaldun	Muqaddimah (Prolegomena) (1981 Prinbceton), Kitab al-I'bar, Al-Tasrif.
Ulugh Beg	Tables of Planetary Motions
Al-Maqdisi	Book of Divisions for the Study of Climate (1897)
Yaquut al-Hamdavi	Mu'jam al-Buldan (Lepzig, 1924), Mu'jam al-Ubada (London, 1913).
Ibn al-Qifti	Tarikh al-Hukuma, (Leipzig, 1903)
Al-Istakhri	Kitab al-Masalik wal Mamalik (abridged) (London, 1800)
Abul Faraj Qudamah	Kitab al-Faraj in Biblioteca Geographorum Arabicorum (Leiden, 1870-94)
Al-Damiri (Zoologist, 1405-)	Hayat al-Hayawan (London 1906, 1908, Tr. Jayakar)
Ahamd Ibn Majid (piloted Vasco da Gama's ship)	Al-Fawaid fi Usul al-Bahr wal-Qawaid (Paris, 1921-23, Tr. Ferrand)

2.5 16th to 19th Centuries

Science in Europe started off in the 16th century, when European scientists re-discovered the 'experimental method', which was a new and alternative way of finding the truth. This new method was a way to systematically test hypotheses and theories and to validate observations and deductions through direct interrogation of nature. Thus, Europe now not only focused on discovering what was new and unexplored but also challenged the established beliefs, thereby laying the foundations of alleviating science as we know it today.

Nicolaus Copernicus is amongst the first scientists who signalled the dawn of science in renaissance Europe. He challenged Ptolemy's geocentric planetary system and proposed instead a heliocentric one. His rejection of an established doctrine is recorded as the first of such major events to have propelled the scientific chain-reaction. This was followed by the astronomical observations of Tycho Brahe (1546-1601), which led Johannes Kepler (1571-1630) to establish his three empirical laws of planetary motion. The seeds of the scientific method, whereby theories and hypothesis were formulated in such a way that they could be tested against accurate observations, were sown during this time. Soon after Kepler, the era of Galileo Galilei (1564-1642) began, during which he developed the telescope, invented the thermometer, used the

motion of the pendulum to measure time and established the science of kinematics. This period is justly termed as the era of the development of the scientific technique, where the emphasis was on the appreciation of the power of scientific instruments.

Galileo was born in 1543 and died in the year 1642; coincidentally the same year that Isaac Newton was born. The physics of Newton during his era is considered to be remarkable in the true sense of the word. It is from here that the foundations of modern science and modern physics were grounded. The full explanation of celestial and terrestrial motions was not given until 1687, when Newton published his Principia [Mathematical Principles of Natural Philosophy]. This work, the most important document of the Scientific Revolution of the 16th and 17th centuries, contained Newton's famous three laws of motion and showed how the principle of universal gravitation could be used to explain the behavior not only of falling bodies on the earth but also planets and other heavenly bodies. To arrive at his results, Newton invented one form of an entirely new branch of mathematics, the calculus (also invented independently by G. W. Leibniz), which was to become an essential tool in much of the later development in most branches of physics. With Newton began the sharpening of the definitions of the scientific vocabulary, especially the basic concepts of space, time and the derived quantities of velocity and acceleration.

As Snow puts it, dating the scientific revolution is 'a matter of taste'; however, the middle of the 17th century is usually regarded as the beginning. At this stage, the journey of science that originated in mystery, had passed through astrology and astronomy, moved on from geocentric to heliocentric descriptions of the solar system, gone from circular to elliptic orbits of the planets, progressed from kinematics to dynamics and finally reached the grand synthesis of Newton and classical mechanics.

In the 17th century, focused and specific interrelationships between science and technology were quite minimal; however by the end of the 18th century, things improved quite a lot. The basis of industrial revolution, which was established in 1765 when Watt invented the steam engine, was solely propelled by invention and not science. However, by the end of the 19th century, the interaction and inter-linkage of scientific discovery and industrial revolution had materialized. As a result, this intertwining of basic science and technological advancement led to the surfacing of integral industries, such as the chemical, engineering, electrical, electronics and transportation industries, as well as the many industrial uses of atomic particles besides others.

Nevertheless, the period of early 18th century up till early 20th century is appropriately denoted as the time when the foundations of modern science were laid. During these 200 years or so, science moved from Newton on to Einstein, from macrocosmos on to microcosmos and from classical physics to quantum physics. The key characteristics of this era include critical observations, ingenious experiments, unique insight and patient incremental understanding, which ultimately led to amazing and unorthodox synthesis and suggestions. This was an era of gradual

Table - 3: Early Scientific Journal

Year	Publication	Details
1665	"Le Journal des Scavans"	<ul style="list-style-type: none"> • French Journal • One of the earliest scientific journals
1665	"Philosophical Transactions"	<ul style="list-style-type: none"> • One of the earliest scientific journals • This British Journal appeared a few months after the French Journal
1687	"Principia"	<ul style="list-style-type: none"> • Newton's great work, which includes his 3 laws of motion and also the law of universal gravitation
1790	"Journal der Physik"	<ul style="list-style-type: none"> • Considered to be the first specialized journal in physics • First issued in Halle and Leipzig
1798	"Philosophical Magazine"	<ul style="list-style-type: none"> • English Magazine
1848	"Science Magazine"	<ul style="list-style-type: none"> • One of the top rated magazines
1869	"Nature Journal"	<ul style="list-style-type: none"> • One of Europe's most famous journals

evolution, intermittent revolution through discoveries, independent development of fundamental modern scientific fields, as well as intertwined and interlinked progression of cross-disciplinary realms. During this time-frame, science was led by innovation breeding innovation, which materialized the establishment of the broadest laws of science.

Following in the footsteps of Newton, the realms of classical physics and celestial mechanics were further developed by eminent persons such as P.S. Laplace, J.L. Lagrange, J.B. Fourier, W.R. Hamilton, S.D. Poisson, C.G.J. Jacobi and H. Poincaré. New and important mathematical methods, including differential calculus and partial differential equations, and concepts including potential energy were established, forming the basis of modern science, which augmented the emerging fields of electricity, magnetism, heat and thermodynamic equilibrium.

Modern science, especially physics, flourished during this period. In 1788, Charles-Augustin de Coulomb (1736-1806) formulated his inverse square law of force for electric charges, which was an evocation of Newton's law for mass. Also in the 1780's, Luigi Galvani (1737-1798) accidentally discovered an electric current in the sense of a continuous flow of charge that could be set up and controlled at will. Later, Alessandro Volta (1745-1827) showed that if the two dry ends of a copper and zinc rod were immersed in sulfuric acid and connected by a wire, a current flowed through the system. This was the birth of the first battery or the Voltaic cell. This discovery laid the foundations of the development of the electrical industry and scientific instruments to measure current and voltage. From here, research in the field of electricity moved from electrostatics on to electrolysis and finally electromagnetism, when in 1820, Christian Oersted accidentally found that an electric current generates magnetism. This discovery was followed by Michael Faraday's discovery of electromagnetic induction in 1831. The discovery of production of an electric current by the motion of a

magnet by Faraday and the discovery of the influence on a magnet by motion of electric charge by Oersted demonstrated that electricity and magnetism are interconnected.

However, the final confederacy of electricity and magnetism was achieved through the work of James Clark Maxwell (1831-1879), who was a great synthesizer. He built upon the concepts of Faraday's idea of the field, Gauss's law of electricity, Gauss's law of magnetism and Ampère's law relating to the current flowing in a wire to the magnetic field around it. Maxwell concluded that accelerating electric charges generate electromagnetic waves traveling with the speed c , independent of their wavelengths and that all electromagnetic waves have the same speed when traveling in vacuum. This synthesis of Maxwell consequently became the theory of light. The speed of light c has become one of the most fundamental constants in all science, and is especially crucial to the theory of special relativity, which was postulated forty years later. In 1887, Henry Rudolf Hertz demonstrated the existence of electromagnetic waves and, later, through the Zeeman and Kerr effects relationships between light and electromagnetism were further substantiated.

The end of the 18th century is considered to be the time when chemistry emerged as a scientific discipline and with this emergence came the first evidence that matter is constituted of atoms. Consequently, in 1808 John Dalton proposed the atomic theory of matter. The discovery of the concept that matter comprises atoms paved the way for the systematic study of chemical phenomena and culminated in the realization that there is a great degree of order in the chemical behavior of different elements. But perhaps, the most fascinating of all realizations was that everything in the cosmos consists of nothing else but the same and finite elements. It is the infinite combinations of these elements and their recycling that defines the infinite variety of nature.

2.6 Physics of the 20th Century

It was quite clear by the beginning of the 20th century that the most fundamental entities of nature are not atoms. It is indeed a great achievement of mankind to have uncovered the secrets of the inner structure of the atom.

Near to the end of the 19th century, scientists realized that classical mechanics had its limitations and was unable to explain a number of upcoming phenomena. Therefore, it was time for a new fusion and a new era, in which revision of established ideas would take place and a broader vision would be established. This was to be the era of Max Planck and Albert Einstein. Both these scientists had a thorough understanding of the subjects of thermodynamics and statistical mechanics and, undoubtedly, were blessed with great scientific intuition. Quantum physics and light quanta evolved due to the resolution of the new phenomena regarding emission and absorption of electromagnetic radiation by matter. The revision of the concepts of space and time, as well as the establishment of the special theory of relativity was postulated from the resolution of the propagation of electromagnetic waves in empty space. Such were the accomplishments of scientists of this era.

Although, relativity resolved the electromagnetic phenomena conflict demonstrated by Michelson and Morley, a second theoretical problem was the explanation of the distribution of electromagnetic radiation emitted by a black body; experiment showed that at shorter wavelengths, towards the ultraviolet end of the spectrum, the energy approached zero, but classical theory predicted that it should become infinite. This glaring discrepancy, known as the ultraviolet catastrophe, was resolved by Max Planck's quantum theory (1900). In 1905, Einstein used the quantum theory to explain the photoelectric effect, and in 1913 Niels Bohr again used it to explain the stability of Rutherford's nuclear atom. In the 1920s, the theory was extensively developed by Louis de Broglie, Werner Heisenberg, Wolfgang Pauli, Erwin Schrödinger, P. A. M. Dirac, and others; the new quantum mechanics soon became an indispensable tool in the investigation and explanation of phenomena at the atomic level.

Indeed, special relativity has provided a new set of rules for measuring time. Absolute time is not how one defines time. Time is a relative quantity and the rate at which it passes depends on one's motion. A general scientific truth thus emerged, which entailed that the laws of nature remain the same, regardless of the relative motion of the observer. It is not only the concept of time which has been revised, but also those pertinent to mass, space and energy. Now, the concepts of absolute time and space of Newtonian mechanics have been replaced by the new absolutes that speed of light c is a constant, which cannot be exceeded. Special relativity has also unified the concepts of mankind regarding mass and energy, by showing the equivalence of both. The discovery of nuclear fission by Otto Hahn and Fritz Strassmann (1938) and its explanation by Lise Meitner and Otto Frisch provided a means for the large-scale conversion of mass into energy, in accordance with the theory of relativity, and triggered as well the massive governmental involvement in physics that is one of the fundamental facts of contemporary science. The growth of physics, since the 1930s, has been so great that it is impossible in a survey article to name even its most important individual contributors.

Among the areas, where fundamental discoveries have been made more recently are solid-state physics, plasma physics, and cryogenics, or low-temperature physics. Out of solid-state physics, for example, have come many of the developments in electronics (e.g., the transistor and microcircuitry) that have revolutionized much of modern technology. Another development is the maser and laser (in principle the same device), with applications ranging from communications and controlled nuclear fusion experiments, to atomic clocks and other measurement standards.

3. PHYSICS IN OUR LIVES

In the last decades, scientific knowledge and technology have grown at a spectacular rate, and had a dramatic impact on society. There is however, a long and complex way to go between a new scientific discovery and its effects on society. Most citizens will only become aware of such discovery, when it concerns a spectacular new scientific insight and, if the media decide to bring it to the people's attention. And then in most

cases they rightly will be told at the same time that it may take many years before we can expect any practical application of this discovery. But it is precisely these practical applications that have an impact on society.

Even if there are no practical applications, scientific discovery still is a cultural enrichment for society. Therefore, science is one aspect of culture. And it would be worthwhile to make this aspect of culture accessible to more people. Nevertheless, scientific discoveries only have a substantial impact on society, if they ultimately lead to attractive new or improved products, with which we will deal in our day to day lives. And for this conversion of science into products, we need technology. Without technology, most of our durable goods, public utilities, consumables and services would simply not exist. And physics is one of the most important sciences that are responsible for these developments.

3.1 Impact of Physics on Mankind

The present age is different from all the previous eras only because of the scientific inventions, which are in daily use of mankind. The life of today's human being is completely dependent upon the machinery and industry. The bicycles, cars, motor vehicles, rails, aeroplanes, telephones, wireless, T.Vs, radios, electrical appliances in houses, hospitals and offices all are due to the application of physical laws. The industrial revolution is based on technology, which is the application of physics and other branches of science. The life is so much dependent upon technology now a days that most of the intellectuals, literary persons (poets and writers) and even the scientists are thinking that the use of mechanics has "made the man himself like a machine". This is an unpleasant aspect of the technological development. We have discussed that the development of science has been continuously in progress since prehistoric times. This speed of development achieved the greatest impetus by the end of 19th century and in 20th century man became able to see into the world of atom and mysteries of galaxies. Man reached moon and explored the deserts of empty space and expanding galaxies.

Moreover, it is hard to maintain that scientific discoveries only have impact on society if they lead to products. One must think about the impact that Galileo had on thinking and religion or the impact of quantum mechanics on philosophy and the arts.

3.2 Physics in Everyday Life

The most basic of the sciences, physics, is all around us. If you have ever wondered what makes lightening, why a boomerang returns, how ice-skaters can spin so fast, why waves crash on the beach, how does a tiny computer deal with complicated problems, or how long does it take the light to travel from a star to reach us? You have been thinking about some of the same things physicists study every day.

Physicists like to ask questions. If you like to explore and figure out why things are the

way they are, you might like physics. If you have had a back-row seat in a concert, and could still hear, you experienced physics at work! Physicists studying sound contribute to the design of concert halls and the amplification equipment. Knowing more about how things move and interact can be used to manage the flow of traffic and help cities avoid gridlock.

Lasers and radioactive elements are the tools used against the war on cancer and other diseases. Geophysicists are developing methods to give advance warning of earthquakes. They can explore what is beneath the surface of the Earth and art the bottom of the oceans. The work of physicists made possible the computer chips that are in your digital watch, CD player, electronic games, and hand-held calculator. It is the physics that lets us watch shows movies, matches, games and news at our houses through TV and VCR. There are so many examples where physics is in use in our daily lives that one cannot mention all in a lecture.

3.3 Physics in Professional Careers

Physics offers challenging, exciting, and productive careers. As a career, physics covers many specialized fields from acoustics, astronomy, and astrophysics to medical physics, geophysics, and vacuum sciences. Physics offers a variety of work-opportunities such as lab supervisor, researcher, technician, teacher as well as manager. Physics opens doors to employment opportunities throughout the world in government, industry, schools, and private sectors.

3.3.1 Elementary or Middle School Teaching

It has been said that children are born scientists. This is the best illustrated by the questions they constantly ask. Teaching at the elementary or middle school level presents the challenge of keeping their curiosity alive while teaching new ideas.

Why do you get shocks in cold as well as during dry weather? Does a stick of dynamite contain force? What makes rainbow from? How cold can it get? Individuals who themselves appreciate science often have a special gift for teaching young children. Curiosity about the world around us is a common bond of children and scientists.

3.3.2 Sports

When you watch an athlete, you are seeing all the principles of physics in action. The bat hitting the ball, the spiraling football, the bend in the vaulter's pole, and the tension of muscles as a weight is lifted illustrate some of the basic laws of physics, like momentum, equilibrium, velocity, kinetic energy, center of gravity, projectile motion, and friction. Knowing these principles of physics helps an athlete or coach improve performance.

3.3.3 Imaging Techniques

Looking inside the body without surgery is one of medicine's most important tools. X-rays, computed tomography, CT scans, and magnetic-resonance imaging are used to determine bone damage, diagnose disease, and develop treatment for various illnesses.

Technicians who use imaging equipment need to be familiar with the concepts of x-rays and magnetic resonance, and to be able to determine how much of this powerful technology to use. Imaging technicians work at hospitals, medical colleges, and clinics.

3.3.4 Automobile Mechanics

Today's automobiles are a far cry from those put on the road by Henry Ford. Computers play a major role in how cars operate. Computers are also used by mechanics to diagnose auto malfunctions. A basic understanding of computer technology is essential in almost every career.

3.3.5 Environment

The 1990s have been called "Decade of the Environment". Environmental physicists are studying ozone-layer depletion and other problems involving the atmosphere. They use acoustics to try to reduce noise-pollution. They search for cleaner forms of fuel, study how smog forms and how to reduce it, and devise ways in which to dispose of and store nuclear waste safely.

3.3.6 Journalism

Science is one of the most exciting assignments a reporter can have. New discoveries, controversial findings, space research, medical breakthroughs, natural disasters, technological competitiveness, and the environment make up a big part of the news. Reporters who have a background in physics have an advantage in being able to quickly grasp technical issues and communicate easily with researchers. Many major daily newspapers in this country have science sections; in addition, science reporting is featured on radio and television.

3.4 How Physics Can be Popularized: The Role of Teachers

Physics can be "popularized" by emphasizing its relevance to life. There are two major aspects of its relevance that can be discussed. First of all, there is the importance of physics in understanding natural phenomena; and secondly, the need of physics in understanding technological developments.

The teacher must arouse curiosity about nature and natural phenomena. To do this, the

teacher can draw attention to the many marvels of nature. If he and his audience have a tilt towards religion, the numerous Quranic injunctions can also be involved to observe and ponder about the natural phenomena. Having aroused curiosity, the teacher can then go on to show how physics has helped us in understanding many of these phenomena. The teacher should also emphasize that the search for truth is an unending one, and there are many areas that need further investigation, which will continue to provide stimulating challenges for generations of physicists to come.

Principles and processes of physics form the basis for most technological devices that have become such an important part of our lives. This includes: automobiles, aircraft, cameras, radio, TV, electrical appliances, computers --- and the list can really go on and on. Again, the teacher should emphasize the fact that to gain a real understanding of the functioning of any or all of these devices one must understand physical principles. Besides devices that we encounter everyday, there is the underlying technological infra-structure that makes all of these things possible and for that again, physics forms the basis.

4. THE ROLE OF PHYSICS IN THE 21st CENTURY

When we talk about the role of physics in the 21st century, there are two things that should be borne in mind.

- Physical principles form the basis for most technological development.
- In general, many new technologies are highly interdisciplinary in character, bringing together concepts from diverse fields. This again blurs the old boundaries and makes it difficult to isolate their role of any one discipline.

The most dramatic technological development of the 20th century was the fabrication of nuclear weapons. It was this, more than any other innovation, that brought physics and physicists to the center-stage in society. Nuclear science has all the powers to develop or destroy the world we live in. It (nuclear science) has been used to build weapons of mass destruction. Despite the continuous efforts during the last half a century to put this genie back into the bottle, there are no signs of it happening. The 21st century will thus, continue to have this technology as one of the major determinants of inter-state relationships. Along with that, the enormous stockpiles of these weapons will continue to represent a serious threat to human-society.

Of course, an understanding of the nucleus has also led to the development of many new technologies that have already benefited us greatly and that have the potential of bringing many more benefits in the next century. Conventional nuclear power from fission based reactors will continue to play an important role, but potentially, perhaps the most significant development for humanity will be the harnessing of nuclear fusion-reactions to generate energy. What is so exciting about this prospect is the fact that fuel for an advanced form of these reactors can be extracted from ordinary water,

with a liter of water yielding energy equivalent to more than fifty liters of gasoline. This means that after the development of fusion-reactors, we will have at our disposal a virtually inexhaustible source of energy.

Another source of energy with a large and inexhaustible potential is solar energy. We are already seeing it harnessed on a limited scale, but for the next century, physicists have the challenge of dealing with the limitations of the present technology and developing new methodologies, which will enable a large scale harnessing of this source.

We have already seen nuclear-radiation and radio-nuclides applied extensively to all the three major aspects of our socio-economic structure: industry, agriculture and medicine. They have also become indispensable tools in many disciplines, as diverse as chemistry, biology, hydrology, oceanography, geology, archaeology, paleontology, environmental science, forensics, genetic engineering and so on. The new century will see an even greater flowering of these applications.

Investigations into superconductivity will lead to many new kinds of applications, in areas such as high speed public transportation, efficient transportation and storage of energy and a multiplicity of devices requiring intense magnetic fields.

Continuing research in condensed matter physics promises to yield major dividends in further enhancing the already phenomenal pace of development of computing power.

Lasers have already permeated into countless devices, many of which are found scattered in ordinary homes. Their potential, however, has not yet been fully exploited, and in the next century we can expect to see them being put to many other uses.

Since the discovery of X-rays at the end of the last century, they have been an indispensable diagnostic tool for the medical profession. During the last few decades, many other physical techniques have become a part of the array of diagnostic devices that now doctors have available. These include, ultrasound devices, gamma cameras, single photon emission computed tomography (SPECT), positron-emission tomography (PET), and magnetic-resonance imaging (MRI). The next century will continue to see the power of physics being brought to bear in new ways to illuminate the working of the human body.

It is not just in diagnostics, but for treatment as well that the medical profession has found the great utility of physics and physical devices. Radiotherapy, laser surgery, microsurgical devices, physical implants; all these and many other are already a part of the medical repertoire. But we have just seen the beginning of this trend and in the future we can expect to have a much more extensive range of such applications.

Understanding of physical process within biological organisms – of which the human body is one example - is at present at a relatively primitive stage. The 21st century

should see a great upsurge in this area, and with that should come totally new approaches to the age old problems of maintaining and improving human health.

The recently acquired ability of biologists to understand and manipulate DNA, the control-center of life processes, has already led to many dramatic applications. But, the full potential of recombinant DNA-techniques have played a very important role in the development of the technology and will continue to do so in the future.

Space exploration should become a mature and well-established activity during the next century. This will involve numerous interfaces with physics at all stages of development.

A common element of all of the expected developments described above is the fact that these are based on the concepts that have already been developed. From the history of physics, we know that the investigation of nature, inevitably leads to radically new insights and new concepts. The qualitative change in our understanding of natural phenomena then suggests new ways of harnessing nature for our own purposes. A very pertinent example of such a development is provided by the way an investigation of the structure of matter led to the discovery of the nuclear force and then to nuclear fission, a means of liberating that force with all its consequent implications for human society. Just a few years before its actual realization, no one could have predicted such a development. Thus, we should expect the unexpected to arise from the investigations into basic physical phenomena that are going on intensively at present. What impact those new discoveries will have on our understanding of nature, and how that new understanding will affect society at large, cannot be predicted.

CONCLUSIONS

Physics has enormously contributed to the process of development and refinement of not only currently utilized technologies, but also those potentially utilizable technologies that are termed as 'the Future Technologies'. Physics is considered to be the most basic of the natural sciences. It deals with the fundamental constituents of matter and their interactions, as well as the nature of atoms and the build-up of molecules and condensed matter. It tries to give unified descriptions of the behavior of matter as well as of radiation, covering as many types of phenomena as possible.

It is unanimously agreed that the computer, the transistor, and the World-Wide Web are among the greatest inventions of modern times. We all know that today's global economy is strongly reliant and linked to applications of these technologies. It is a true fact that the day-to-day life of millions of people, across the globe, would be profoundly different without the presence of these technologies to facilitate them. The present status of the USA as an economic superpower is primarily due to its dominance in the realms of computer and information-technology. Moreover, high figures of GDP, in Japan, Taiwan, countries of Western Europe, and others, is also partly due to their acceptance of, and contribution to, the era of the information-age. Interesting to note

is the fact that physicists invented the computer, the transistor, the laser, and even the World-Wide Web.

In the world of today, it is a fact that an individual knows more fundamental physics than knowing how to use it presently. The application of this available knowledge to integral fields, such as condensed-matter physics, chemistry, biology, and the associated technologies like material science, electronics, photonics, nanotechnology, and biotechnology, is perhaps the only way to make easy progress now. By doing so, the physicists of the world may well be able to lay the foundation for a new and higher level of fundamental experimental physics.

Learning from the history, we now know that physics impacted positively on our society and culture, it revolutionized our way of living number of times in the past, and possesses the powers to do so many times ahead and lead us to even more thrilling experiences, be it in space science or nano-science. The questions now arise for us, are to ascertain how we can make best use of this existing knowledge of physics, that is to further disseminate and popularize it? What areas of physics should be given high priority for development? What can be done to synergize global efforts to satisfy the quest and thirst for more knowledge, especially in the field of physics? And finally who should take lead and pain in carrying out these activities?

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THE ROLE OF SOME GREAT EQUATIONS OF PHYSICS IN OUR LIVES

Riazuddin

*National Centre for Physics, Quaid-i-Azam University
Islamabad, Pakistan*

ABSTRACT

The paper will first discuss the ranking of important equations in Physics, in the light of the poll recently conducted. Then I will bring out the unifying power of a great equation. Finally, I will discuss their roles in our lives.

Recently a poll of “Best Equation” was conducted. The result of this poll was published in a British Daily Newspaper, “Gaurdian” on Oct. 06, 2004.

RESULTS OF THE POLL

1. Maxwell’s equations:

$$\nabla \cdot \mathbf{D} = 0$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$

2. Euler’s equation:

$$e^i \quad 1 \quad 0$$

“Most profound mathematical statement ever written” said one reader and it contains nine basic components of mathematics in a simple form.

3. Newton’s equation:

$$F = ma$$

4. Pythagoras’s theorem:

$$a^2 + b^2 = c^2$$

The most famous theorem in all mathematics; basis of Euclidean geometry:

5. $H = E$

Basic equation of Quantum Mechanics

6. Einstein's relation:

$$E = mc^2$$

7. Boltzmann's equation:

$$S = k \ln W$$

8. $1 + 1 = 2$

I will add two more equations for the reasons that I will discuss

9. $R = \frac{1}{2} g R = 8 GT$

Basic equation for Einstein's theory of gravity.

10. Dirac's equation:

$$i \hbar \gamma^\mu \partial_\mu \psi - m c \psi = 0,$$

Which governs the behavior of the electron. Robert Crear (Department of Philosophy at the State University of New York at Stony Brook), who coordinated the poll said, "The unifying power of a great equation is not so simple as it sounds. A great equation does more than set out a fundamental property of Universe, delivering information like a sign-post, but works hard to wrest something from nature". We will see the illustration of this later.

An equation represents a universal physical law in a simple form that is obeyed by the various physical quantities. The act of writing down a fundamental law, usually in the form of a differential equation, is a rather singular and rare event. But is that all? Some people might think that this is all needed and the goal of theoretical physics would have been achieved by obtaining a complete set of physical laws. In reality we need to have a set of initial conditions that tell us the state of a system at a certain time, to model a physical reality. Neither the initial conditions nor the values of the parameters in the theory are arbitrary, rather they are somehow chosen or picked out very carefully. For example, as stated by Hawking, "if the proton-neutron mass difference were not about twice the mass of the electron, one would not obtain the couple of hundred or so stable nucleides that make up the elements and are the basis of chemistry and biology". Even so, we have been able to solve some of the basic equations only for very simple systems; more often than not, we have to resort to approximations and intuitive guesses of doubtful validity. For example, as pointed by Hawking, "although in principle we know the equations that govern the whole of biology, we have not been able to reduce the study of human behavior to a branch of applied mathematics".

THE ROLE OF EQUATIONS IN OUR LIVES

I will discuss it in chronological order, rather than on the votes obtained in the poll that I mentioned earlier.

Newton's Equation:

$$F = ma$$

It is the soul of Classical Mechanics. The right-hand is the product of two terms, mass and acceleration. The acceleration is a purely kinematical concept, defined in terms of space and time. Mass is an intrinsic and measurable property of a body. In modern foundations of Physics, it is energy and momentum which appear rather than force. However, force is the time-derivative of momentum and space-derivative of energy and, as such, not quite so removed from modern foundations. Even so, force is something one can feel, for example, by placing a weight on the front of one's hand.

Together with Newton's Law of Gravitation, a single law of force of considerable simplicity, $F = ma$, provided the greatest and most complete success in planetary astronomy. The astronomical applications of the laws of classical mechanics are the most beautiful, but not the only successful applications. We use these laws constantly in everyday life and in the engineering sciences:

Bridges do bear their loads, artificial satellites do orbit around the earth, space-crafts do reach their destinations.

Maxwell's Equations

$$\begin{aligned} \vec{\nabla} \cdot \vec{E} &= \rho \\ \vec{\nabla} \cdot \vec{B} &= 0 \\ \vec{\nabla} \times \vec{E} &= -\frac{\partial \vec{B}}{\partial t} \\ \vec{\nabla} \times \vec{H} &= \vec{J} \end{aligned}$$

The laws of electrodynamics, which expressed all known facts at the time Maxwell began his work, are described by:

In the absences of sources

$$\vec{\nabla} \cdot \vec{E} = 0, \vec{\nabla} \cdot \vec{B} = 0$$

Maxwell noticed that the last two equations lack symmetry. Maxwell removed this lack of symmetry by modifying the last equation to:

$$\vec{\nabla} \times \vec{H} = \frac{\partial \vec{D}}{\partial t}$$

The search for symmetry is part of the “architectural quality of Maxwell’s mind” and that he “was profoundly steeped in sense of mathematical symmetry”. In 1864 Maxwell predicted the existence of electromagnetic radiation, including, but not limited to, ordinary light. Maxwell’s new radiation was subsequently generated and detected by Hertz, two decades later. Maxwell unified electricity and magnetism and, as a result, electromagnetic radiation in the form of light, radio-waves and X-rays provide many of the conveniences of modern life viz., lights, television, telephones, etc. Anybody who switches on a color-TV might reflect on it. Over the 20th century, its development and its marriage with quantum theory has revolutionized the way we manipulate matter and communicate with each other.

For Physicists, for the above reason and for the following one, Maxwell has far higher claims: Maxwell’s Theory defined a preferred velocity, the speed of light, whereas the Newtonian theory was invariant if the whole system was given any uniform velocity. It turned out that the Newtonian theory of gravity had to be modified to make it compatible with the invariance properties of Maxwell’s Theory. This was achieved by Einstein in 1905 for his theory of relativity, and in 1917 when he formulated his *General Theory of Relativity*. No wonder that Maxwell’s equations got the highest number of votes in the poll.

Boltzman’s Equation

“The law that entropy always increases - the second law of thermodynamics - holds, I think the supreme position among the laws of Nature”, Eddington. The entropy of a macroscopic system is a measure of the number of microscopic states in which the system can find itself at a given energy or temperature – it can therefore also be thought of as a measure of disorder.

The Boltzman’s equation,

$$S = k \ln W$$

provides an understanding of the second law of thermodynamics in terms of a connection between entropy and probability – one of the great advances of the 19th century.

An immediate consequence is that a particle would like to decay into lighter ones (unless there is some selection-rule to forbid the decay) since the largest number of microscopic configurations has the greatest probability. This is what is observed in nature.

One meets the concept of entropy and the Boltzman equation in communication-theory when we remember that information in communication-theory is associated with the freedom of choice we have in constructing messages. Thus, for a communication-source one can say, just as one would also say of a thermodynamic

ensemble: "This system is highly organized, it is not characterized by large degrees of randomness or of choice – that is to say, the information (or the entropy) is low". Thus, the transmission of a message is necessarily accompanied by a certain dissipation of information that it contains – an equivalent of second law of thermodynamics in information theory.

Suppose we have a set of 'n' independent complete messages, whose probabilities of choice are P_1, P_2, \dots, P_n , then we have entropy-like expression given by Boltzman equation, which measures information:

$$S = -k \sum_i p_i \ln p_i$$

where 'k' is a positive constant, which amounts to a choice of unit of measure. This emphasizes the statistical nature of the whole ensemble of messages, which a given kind of source can and will produce and plays a central role in information-theory as measures of information, choice and uncertainty.

Einstein's Relation

$$E = mc^2,$$

is an important consequence of Special Theory of Relativity. A question was asked in BBC's program "Brain Test" in 1930's, whether one could think of any practical applications of Einstein's relativity. One could not, until the study of nuclear reactions became possible, where neither mass as such, nor the kinetic energy is conserved, but the relativistic energy is conserved:

$$E = mc^2$$

Kinetic Energy [$E = mc^2$]

$$c^2 m$$

(which has disappeared?)

i.e. mass – energy accurately balance off and not convertible to other forms of energy. To illustrate it, let us consider the (D, T) reaction, which is central in achieving controlled nuclear fusion



The total mass on the left side exceeds that on the right side, giving:

$$mc^2 = 17.6 \text{ MeV}$$

which is the energy released in the reaction. The relativistic energy is conserved

although the system is non-relativistic, since no particle is moving with a speed close to the speed of light. If there were no $E = mc^2$, there would be no nuclear power. Another example is that of Stellar Energy. The energy of the Sun is generated through the fusion-reaction:



The energy release per helium atom formed is:

$$[4m_p - 2m_e - m(\text{He})]c^2 = 26.7 \text{ MeV} + Q$$

About 25MeV heat the Sun. Note that neutrinos are given out, so that the Sun is a powerful source of electron-type neutrinos. Neutrinos interact very weakly with matter, so that nearly all the neutrinos produced in nuclear reactions in the Sun escape into space, reach the Earth and have been detected and resulted in award of the 2001 Nobel Prize to Ray Davis and Koshiba. "If there were no $E = mc^2$ and no neutrinos, the Sun and stars would not shine. There would be no Earth, no moon, no us. Without them we would not be here" Boris Kayser.

$$H = E$$

this is the basic equation of Quantum Mechanics.

The Concept of energy-gaps is purely quantum mechanical – a crucial concept for many applications. The presence of gaps (i.e. energy-bands, where there are no permissible energies) that may occur between energy-levels and the extent to which they are filled by electrons determine the electronic-transport properties of solids. It is a key-concept in building semiconductor devices, which have revolutionized communications, control, data-processing, consumer-electronics and globalization of information. Tunneling is another important concept, which quantum mechanics has made available. Due to quantum uncertainty, on the tiny quantum-scale, particles exist only as a cloud of probability unless they are actually observed. Thus, electron would have to be smeared out with some probability distribution. Thus there is a finite

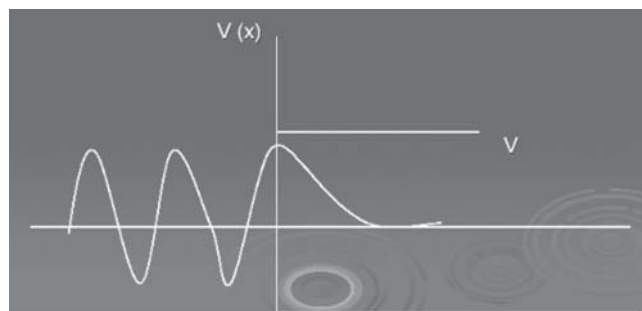


Figure - 1

probability of particle crossing from a classically allowed region of space into one that is classically forbidden (see figure-1), known as tunneling. This has many applications, for example, fusion-reactions in stars where, even at stellar temperature, the nuclei do not have sufficient kinetic energy to overcome their mutual coulomb-repulsion for fusion to occur. Quantum Mechanical-Tunneling through the coulomb-barrier, permits fusion to occur at much lower temperature. Another application is Tunnel Diodes, which respond quickly to the voltage-change.

Einstein's Equation for Gravity:

$$R - \frac{1}{2} g R = 8 GT$$

It is a remarkable equation, relating how matter and energy (determined by fundamental particles and forces) described by the Right-Hand Side (R.H.S.) influence the Left-Hand Side (L.H.S.) representing the curvature of space and time and expansion of the universe and vice-versa. Here, one sees how microphysics determines the evolution of the universe. Thus, this equation can be used for the simulation of the early universe. If we extrapolate backwards the temperature-time relations from Einstein's equation, we can study the early universe by recreating in terrestrial laboratories a little piece of primordial soup, which are the elementary particles produced and studied at accelerators. Such an extrapolation successfully predicts that three minutes after the Big Bang, the primordial neutrons and protons form 75 percent of hydrogen and 25 percent helium, the so-called nucleosynthesis. We can now extrapolate back in the laboratories in time at 10^{-10} seconds after the Big Bang and would reach to 10^{-12} seconds after the Big Bang in 2007.

Dirac's Equation:

$$i \hbar \gamma^\mu \partial_\mu \psi = m c \psi$$

Dirac combined the special theory of relativity with quantum mechanics and obtained his equation from pure logic. The Dirac equation has profound consequences. It naturally comes out that the particle it represents has spin $\frac{1}{2}$; anti-matter must exist, to each particle there is an anti-particle, and gave a new meaning to vacuum in the microscope world – vacuum is a seething foam of particle-antiparticle pairs, hopping in and out of a united existence, and may be the seed of everything we see in the universe. When the positron, the antiparticle of electron, was discovered Dirac is said to have remarked: "This equation is smarter than its inventor."

Anti-matter caught the imagination of science-fiction workers (Star Trek's faster-than-light science-fiction space-ships use antimatter power; antimatter annihilates with ordinary matter, disappearing in a puff of energy and thus provides the perfect fuel). But anti-matter has been used for real. Just to indicate one practical application: PET scan. Positron Emission Tomography can be used to reveal the workings of the

brain. In PET, the positrons come from the decay of radioactive nuclei in a special fluid injected into the patient. The positrons then annihilate with electrons in nearby atoms, in the form of 2 gamma rays – which shoot off in opposite directions to conserve momentum.

Both Maxwell's equations and Dirac's equation gave much more than what was put in, purely from mathematical symmetry and analogies: *they wrest some thing from nature.*