The Significance of Physics in everyday life

By Dr. Umesh Moharil | August 15, 2020

Preface

Physics is the science of matter and its motion, space-time and energy. Physics describes many forms of energy - such as kinetic energy, electrical energy, and mass; and the way energy can change from one form to the. Everything that surrounds us is made of matter and Physics explains this matter as combinations of elementary particles which are interacting through fundamental forces. Nature is almost Physics (the word Physics itself is derived from Greek "physis" meaning nature) and it always seeks for explaining the unknown around us with a broad scope. On one frontline, Physics deals with elementary particles such as quarks, lepton, etc and explains how these particles interact to form matter; while on the other frontline it deals with large-scale planetary systems, galaxies and universe. Unless categorized, it is difficult to get an idea about the broader scope of Physics for example: mechanics, electricity, heat, sound, light, condensed matter, atomic physics, nuclear physics, elementary particle physics, astrophysics, nanotechnology and the list goes on.

Physics had strengthened and supported all fields of engineering and many other branches of sciences and technology. Physics is the foundation for modern technological revolutions that changed our life and helped to flourish the modern world. Much of modern technology is the result of research in physics including the transistor and integrated circuits, which are at the heart of any modern technology. Physics is thought-provoking and provides a way of looking at nature from the bottom up. The engineer understands to build, the physicist builds to understand.

Physics is all around us. We can find Physics principles behind working of any daily-life gadget such as an electric light, electricity, the working of our vehicle, wristwatch, cell phone, CD/DVD player, tiny music players, the mass storage devices such as hard drives and USB flash drives, radio, LCD displays, plasma TV, computer, and many more – the list goes on. In the present article an attempt has been made to elaborate the role of Physics in other branches of sciences and engineering.

The Legacy of Classical Mechanics

The term classical mechanics was coined in the early 20th century to describe the kinematics developed by Galileo and the mechanics developed by Sir Isaac Newton and many others. Classical mechanics is the set of physical laws that governs motion of bodies and also describes the mathematics of that motion. Much of the physics that describes everyday phenomena is classical physics.

In astrophysics the laws of mechanics enables us to deal with astronomical objects such as planets and their orbital motion, stars and galaxies. Classical mechanics explains the motion of macroscopic objects from projectiles to parts of machinery and is essential to civil, mechanical, and aeronautical engineering. It enables us to design everything from roads, buildings, dams, bridges, milling machines, clocks, ships, sewing machines, etc. Newton's laws are used to design satellites and sending spacecraft. Classical mechanics also lie behind geology and gives an understanding of different geological processes such as earthquakes.

The matter can conveniently be described as being in one of three phases – solid, liquid and gas. Plasma is another phase of matter which cannot be easily classified as solid, liquid or gas in which the atoms are ionized and forming an electrically neutral mixture. Gases and liquids are commonly designated as fluids. Classical mechanics explains behaviour of gases using the kinetic theory of gases. The foundation of fluid mechanics is set by many physicists such as Pascal, Archimedes, Bernoulli and many others. The design of airplanes and automobiles, sports utilities including bats and balls, etc is what we call as aerodynamics to counter the pressure arising from air during the motion.

Classical mechanics also explains the motion of mechanical waves that explains sound propagation. In brief, classical mechanics explains almost everyday phenomenon in nature.

Electricity and Magnetism

Orested, in 1820, while preparing a demonstration lecture for his Physics students observed that electric current in a wire can deflect a magnetic compass needle. Michael Faraday (1971-1867), a chemist and physicist, contributed to the fields of electromagnetism and electrochemistry. Faraday established the basis for the concept of magnetic field, electromagnetic induction, diamagnetism and electrolysis. His inventions of electromagnetic rotary devices formed the foundation of electric motor technology, and it was largely due to his efforts that electricity became viable for use in technology. In the 19th century, James Clerk Maxwell combined electricity and magnetism by putting Faraday's ideas into mathematical form and provided electromagnetism a strong theoretical base. He showed that light is an electromagnetic wave that travels through empty space. Other electromagnetic waves besides light also travel through empty space. Maxwell's theory also showed that electromagnetic waves travel with the same speed (the speed of light), even if the person who sees it is moving.

Understanding the behaviour of electrons at both macro and micro levels is a must when designing circuits now-a-days for compressing electronic devices. The knowledge of Maxwell's equations is fundamental principal of all large-scale electromagnetic and optical devices such as motors, radio, television, microwave radar, microscope and telescopes. Without the pioneering work of these Physicists it would not have been possible today for us to see the revolution in telecommunication engineering. The knowledge of laws of electrostatics and electrodynamics is a must while designing the instruments such as fibre optics for telecommunication.

Electrical engineers use the physics of electromagnetism to build electric power plants and transmission lines, while electric motors and batteries power everything that requires electricity. Radio waves and radar have revolutionized communications, making television sets and cell phones possible and they also power the microwave oven. The electrical attraction of protons and electrons is the basis for chemistry.

A "Thoughtful" Revolution: The Theory of Relativity

The Special Theory of Relativity (STR) predicted in the year 1905 by Albert Einstein revolutionized many ideas in classical mechanics. STR predicted that the faster the object travel through space, the more massive is become and it also becomes thinner in the direction of motion. The time slows down and the width changes. Another remarkable consequence of special relativity is the famous equation $E=mc^2$, which says that mass is just another form of energy. $E=mc^2$ is also responsible for the release of energy from fission of uranium in a nuclear reactor, and this energy is used around the world to make large amounts of electric power.

Today, the general theory of relativity is well-tested and is used to accurately determine the location using a GPS (Global Positioning System) device. General relativity and particle physics are the basis for modern cosmology, which is now one of the most exciting fields of science for the study of the origin and evolution of the universe.

Quantum Mechanics

The foundations of quantum mechanics were established during the first half of the twentieth century by Werner Heisenberg, Max Planck, Louis de Broglie, Niels Bohr, Erwin Schrödinger, Max Born, John von Neumann, Paul Dirac, Wolfgang Pauli, Richard Feynman and others. Quantum mechanics describes how electrons can only travel around the nucleus of an atom in orbits with certain specific energies. This enables us to have understanding of origin of electromagnetic radiations. Because the energies of different states of an atom are known with high precision, we can create highly accurate devices such as atomic clocks and lasers.

In 1917 – Albert Einstein performs fundamental studies on the nature re-derived the Max Plank's law of radiation and introduced the concept of spontaneous and stimulated emission which is basis of laser. The work done by Charles Townes (Nobel Prize in Physics, 1964), Arthur Schawlow, Gordon Gould Theodore Maiman from 1953 – 1960 made the concept of laser come true. Today, laser is the key component in many medical, industrial, military and consumer devices. Laser-based fibre optics made it possible to have faster communication in voice, internet, and telecommunication. Laser is also used in plenty of medical procedures from eye-surgery to skin-cancer removal. CDs, DVDs, scanners, printers, barcode readers, and holograms are among few consumer products that use laser.

The realization of electron behaving as a particle and wave lead to the invention of semiconductors, and then obviously the integrated circuits, chips, and microprocessors.

This is how we make transistors, microscopic electrical on-off switches, which are the basis of cell phone, tiny music players, PC, and all the modern electronics that has transformed our business, economy and our lives. It is has been estimated that about one third of the world's manufacturing economy is actually based in some way on the principles of quantum mechanics. In the present computing technology the CPUs/microprocessors required packing of transistors of a few nanometer into a tiny area to achieve greater density. However, this miniaturization has reached the technological limitation. Reducing the size of a transistor below current limit (around 7nm) would make transistors unstable by the principles of quantum mechanics. The next technology in development is Quantum Computing. Quantum computers would be able to deal with the limitations posed by current technologies of classical computing. According to estimation, quantum computing would be able to perform the tasks in few minutes that otherwise would require around 10,000 years of processing with present computing technology. Although quantum computing is in infant stage, but the recent developments by Google, D-wave, IBM, Intel, and Microsoft have paved the ways for their coming the dream of quantum computing into reality.

Quantum Mechanics is vital to everyday life. Quantum Mechanics is the underlying mathematical framework of many fields of physics and chemistry, including condensed matter physics, solid-state physics, atomic physics, molecular physics, computational chemistry, quantum chemistry, particle physics, and nuclear physics.

Nuclear Physics

Nuclear physics has a role in energy production and national security. Besides powering reactors to generate electricity, nuclear reactions are what makes the sun shine, and what keeps the inside of the earth hot and molten – volcanoes are powered by radioactive decay deep in the core of the earth. Nuclear physics is crucial for astrophysics, since the source of energy for stars is nuclear fusion. The fusion of hydrogen in stars also produces other atomic nuclei, and stars are the source of all elements up to iron.

The heavier nuclei are produced when a star explodes in a supernova, and scattered throughout the universe. Caught in orbit around other stars, this nuclear stardust gradually accumulates, attracted by gravity, and forms some rocky planets like ours, with all the elements needed for life.

Physics in Bio-Engineering

Physics is essential to the life sciences such as biology and medicine. Magnetic resonance imaging, which won the 2003 Nobel Prize in medicine, is based on a phenomenon called nuclear magnetic resonance, which won the 1952 Nobel Prize in physics. It relies on the nucleus of every atom having a quantum mechanical property which is called "spin" and which makes the nucleus behave like a tiny bar magnet. Other medical imaging techniques include x-rays (which won the very first Nobel Prize and were used by physicians within months of their discovery), the CT scan, and the PET scan.

CT scans use x-rays to image soft tissue, bone, and blood vessels, and to find tumors, while PET scans use positrons, which are the anti-particles of electrons and are emitted in the radioactive decay of certain nuclei, to examine the functioning of cancer cells, the heart, and the brain. Radioactive tracers are also used for medical diagnosis, to see, for example, blood clots or cancerous tumors. Irradiation by radioactive emissions, x-rays, or particle beams is used for therapy; about 10,000 cancer patients are treated every day in the United States with electron beams from linear accelerators. Altogether, nuclear medicine is now used to diagnose or treat one third of all patients in United States hospitals.

Medicine and biology also benefit from tools developed for particle physics research, such as accelerators. A synchtrotron light source is a special kind of accelerator developed to provide intense beams of ultraviolet light and x-rays, allowing the structure of proteins, enzymes, and viruses to be examined and aiding in the design of drugs. Synchrotron light sources have also been used to solve the major structure of the ribosome, the cell's factory for assembling proteins. In industry, they are used for non-destructive trace elemental and chemical analysis on samples ranging from art objects to semiconductor surfaces. The use of beams of atoms from accelerators to embed doped layers in semiconductors is essential to the multi-billion-dollar semiconductor industry. The same process is used to harden surfaces such as those of artificial hip or knee joints, high-speed bearings, or cutting tools.

Physical laws and methods are important for biochemistry and the processing of information inside cells. Biophysicists study the basic physical properties of biological systems (such as elasticity of DNA and DNA-protein interactions) and apply physical techniques to the modeling of neural, genetic and metabolic networks.

Thermodynamics

Thermodynamics, the way in which heat and energy are stored and transferred, was also developed in the 19^{th} century, and yet its principles remain essential to such diverse areas as refrigeration, chemical engineering, internal combustion engines, and earth science. Driving a hybrid-powered automobile is in fact a daily lesson in energy transfer and storage. Heat transfer is what drives the weather, and understanding the heat balance of the Earth is critical to knowing what should be done about global warming.

The extremely broad range and depth of physics make it both important and fascinating. Physics continues to explore its own very fundamental questions, such as the unification of the forces of nature, the behaviour of nanoparticles, and the dynamics of chemical reactions.

At the same time, it provides the foundations for much of modern science and engineering, and explains why almost all the things we take for granted in our everyday lives work. Truly, physics is everywhere.

A solid background in physics will prepare you to be a leader in our increasingly technical world.

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