SCOPE AND CAREER OPPORTUNITIES THROUGH PHYSICS

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This article discusses what Physics encompasses as a subject upto Intermediate level and application of it can lead to as one pursue the same beyond +2 level. It also touches upon career opportunities available to Physics graduates. The purpose of the article is to illustrate for students of +2 Science stream and physics undergraduate students, possible opportunities which physics offers as a discipline and also to motivate undergraduate physics students who may otherwise be pursuing graduation in absence of any (so called) better opportunity, just for sake of graduation, a most likely contemporary scenario.

Physics is broadly classified into mechanics, heat and thermodynamics, waves, optics, electromagnetism and modern physics as taught upto Intermediate level in present system. One often encounters a phenomenon that deals with more than one of these areas simultaneously. In this article, we want to see what are the different phenomena and applications physics deals with. Many of the phenomena that are discussed in this article may require one to go beyond the +2 level techniques though fundamental principles remain mostly same. Therefore, it becomes important to go through scope to appreciate importance of the subject.

Primary objective of mechanics is to deal with motion, different laws that govern motion, cause and effect. Well, cause and effect is at the foundation of any science. Mechanics tries to understand motion in terms of Newton's laws and conservation principles. For this, it defines and deals with physical quantities like position, momentum, force, energy etc.....

Laws of mechanics are used to understand what happens in sports, e.g. in cricket: spin, swing, trajectory while throwing and similarly in football, base ball etc... Well-known scientist Hemholtz used analogy of a pump to explain mechanism of heart. As students learn: motion is possible only due to action-reaction forces (for example that of rockets) and friction (in day-to-day life). Understanding centre of mass and motion of and around centre of mass are very important for machines and structures. It is important to give thought to how boomerang works, how we balance ourself or how animals use their tail while in different state of motion. The recent Hollywood movie *Avatar* shows tails of aliens fairly accurately. One must note here that stunt sequences in *Hindi* movie are often unrealistic from the viewpoint of Physics.

Study of motion of projectiles is important from the point of view on sports, launching missiles and firing rockets. This also requires rotational motion of earth to be taken into consideration (using pseudo force called Coriolis force). Coriolis force is useful in understanding cyclones, water currents, whirlpools and weather pattern. Circular and rotational motions cover wide range of

interesting areas. These include design of curved roads and racetracks, motion of divers and ice skaters, and balancing in different parts of machines that uses motors. Gyroscopes are used in navigation for ships, planes and automatic guiding systems, including missiles.

Interaction between two different objects in motion is a useful study based on indoor games like carom, billiards to guide planetary probes using gravity of a planet (as in case of pioneer and voyager) and scattering of elementary particle. One such experiment by Rutherford in late nineteenth century of scattering of alpha particles by Goldfoil lead to understand atomic structure and latest Large Hardon Colliders (LHC) to understand mysteries of fundamental force and origin of universe.

Study of simple oscillation turns out to be useful in understanding of vibration of different structures, machines to acoustics. At molecular level, using quantum nature of the world one can understand properties of material and design new materials.

Motion in presence of gravitational field applies to motion of planets and satellites, to galaxies and launching of man-made satellites. Understanding gravitation in finer detail is important for Geo-Positioning System (GPS) to mobile communication. Satellites not only have application for communication and military purpose but also for spying economic benefits in this globalised economy. Most of these are taken for granted by present generation students.

Understanding of sound/mechanical waves are not only important for musical instruments but extends to acoustic design of auditorium, to ultrasonic for medical diagnosis, to Doppler radar for prediction of calamities like Tsunami, weather forecasting and use by traffic police for measuring speed of vehicles. Different types of waves generated during earthquake allow to locate its epicenter from anywhere on the earth.

Study of elasticity is useful in structural strength and design, to design strong materials for various applications.

Understanding properties of fluids has an interesting event in the life of Archimedes. This is of course related to loss of weight or floating objects. Surface tension is important in plants, detergent and it has also been used in understanding of nuclear property in liquid drop model. Change in melting and boiling point of liquid with impurity has interesting application in freezing mixtures, anti-freeze solvents, to cook food. Other than static fluid it is extremely interesting to understand fluids in motion. This has application in sports (remember reverse swing in Cricket), generation of wind power, aerodynamic design of simple automobiles to aeroplanes and space launch vehicles, flow of blood in veins to flow of fluids through different systems in plants and those in machines like automobile engines. Magneto-hydrodynamics is an important branch in astrophysics and is also useful in controlling plasma especially for controlled fusion reaction. Computational fluid dynamics has turned out to be extremely rewarding branch with variety of applications.

Thermal properties of substances have their roots in motion of atoms and molecules. We have made sufficient progress to control and manipulate these properties to use it for our benefit. Expansion properties of metals are used in

bimetallic strip of starters, that of liquids are used in simple thermometers and that of gases have been used for example in storage of liquid petroleum gas for household cooking purpose. Refrigerators, water heaters, air conditioners are also similar examples. These properties and laws also help us to understand and predict weather patterns and understand effect of pollution on weather conditions. Changing properties of substances as melting point using salt (to melt snow) or boiling point using pressure (as in pressure cooker), anti-freeze in lubricants and fuels are such examples. Understanding the relationship between various parameters also helps in designing new materials with designed properties. Invention of heat engine has changed the history and geography of mankind.

Thermal conductivity helps us in designing engines and other materials. As an example, copper bottom vessels have been designed keeping in mind high conductivity of copper. Understanding convection is useful in understanding climatic changes, ocean currents, weather pattern, etc. As a simple application, one needs to understand need of intermitten stirring when heated using microwave as compared to traditional cooking on stoves.

Black body radiation curve matches with spectrum from (i) tungsten filament, (ii) Sun, (iii) nuclear explosion, (iv) any type of flame, and (v) microwave background radiation. Colour and brightness are related to temperature by Wien's law ($l_m T = 0.29$ cm °K). This has direct application in Colour Physics. Understanding of black body radiation curve has also allowed understanding of evolution of universe.

Thermodynamics deals with macroscopic properties of fluids that can be understood as due to collective behaviour of $\gg 10^{26}$ molecules. This is understood in terms of kinetic theory of matter and its success is direct evidence of atomicity.

Study of behaviour of specific heat has led to discovery of super-conductivity-fluidity. It helps understanding climate of Mumbai (island city) as compared to other inland cities in terms of high specific heat of water. Discontinuity in specific heat of H_2 is direct evidence of quantisation and equipartition of energy. It is also an evidence of rotation and vibration of molecules.

Low temperature physics involves thermodynamics of molecular and nuclear magnetic systems. Possibility is seen of manipulating atoms in a phenomenon called Bose-Einstein condensation at nano Kelvin temperature that can help to develop exotic materials.

Thermodynamics is used in design of internal combustion engines, conventional and nuclear power plants, propulsion system for rockets, missiles, aircraft, ships and land vehicles. It helps in designing fuel efficient, energy/cost saving systems.

Thermodynamic principles are also applied to communication and information theory, and to chemical and biological systems. In the latest development, Einstein's general relativity is viewed as thermodynamic limit of statistical theory with atoms of space-time being the microscopic constituents.

Optics deals with light in two ways. One, its propogation through different media, what is known as geometrical optics; and second, physics of its interaction with itself and to different configuration of optical devices, known as

physical optics. Lenses, camera, microscopes, telescopes, etc., are devices that work on these principles. Diffraction, interference and polarisation are the physical phenomena involved in interaction of light that helps us to understand molecular and crystal structures. LASER has its application in medicine, surgery, defence, entertainment etc... LASERs also have found their way into our homes through CD/DVD players.

Electricity has been blessing and at the same time has been a problem for production to meet its demand. Electromagnetic waves are used in microwave range for cooking as well as for telecommunication. They are also used in missile and rocket guiding systems. Magnets and electromagnets have found their way into speakers, magnetic door catchers and in medical applications. Photocopiers, smoke precipitators, electric shockguns are a few common examples where principles of electromagnetic theory are used.

Progress in communication has been possible due to understanding of production, propagation and detection of waves of different kinds. One needs to understand various parameters of wave which are involved and how they are related. Today we are able to talk across continents using mobile phones, know our position with GPS system and transfer large amount of data using internet which may use wireless or optical cable transmission.

Electromagnetic waves in different domains are used for various applications. Radio waves are used for telecommunication and navigation. Microwaves are used for cooking, mobile links and telecommunications. Infra-red are used in sensors, imaging, night vision, etc. Visible range is the one to which our eyes are sensitive. X-rays are used for study of crystal structures, security systems, medical application and even detecting cracks in the rocks. Gamma rays are used for radiation therapy to treat disease like cancer.

Laws of physics are different in the domain of atoms and molecules. The atomic world exhibits quantum nature. It is our understanding of these laws that allowed us to manipulate crystal structures to reach present stage of development of electronics, which has revolutionised quality of our life. Attempts are being made to manipulate atoms to reach power of tera-flop computers.

Photosynthesis and response of eye are based on photoelectric effect. Spin flip transition of outermost electron of Cs^{133} is used to calibrate one second. This is what we call atomic standard clock. Wave nature of electron beam is used in electron microscope to view substance at micrometer level. Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM) are based on quantum tunneling effect and are used to observe at atomic level and study biological processes, respectively.

Study of matter at nuclear dimensions exhibit two new types of forces, namely, strong and weak nuclear force. Strong nuclear force has direct relation to nuclear energy, which has civilian as well as military use. Weak force holds keys to some of the cosmic mysteries that we are trying to understand through experiments like Large Hadron Colliders (LHC).

Description of scope of physics as discussed above is suggestive and not exhaustive and one can add many such examples.

Purpose of any physics course/curriculum would introduce in college for students to these phenomenon and laws governing them. This requires students to grasp the basic concepts well enough and acquired necessary skills involved to be able to contribute to the society.

The processes one has to deal with, at frontier level are too complex and involves large number of phenomena to be addressed simultaneously.

To identify the area of interests in physics for a student, should develop her/his extra ordinary skill in that particular area along with the capability by the time of their gradution. Today many excellent carreer options are available for students, who would like to pursue physics at frontier level as their carreer. In the preceding paragraphs, applications described also gives the indication of possible areas available for one to contribute. A professional physicist is expected to invent new physics, study new phenomenon, understand new processes and develop new applications for the benefit of mankind.

However those who donot want to be a researcher, also can have excellent career opportunities after becoming physics graduate. Physics learned in the right spirit develops analytical abilities which are very useful in those career which look for such abilities rather than background training in a specific area. Software development, data analysis in knowledge industry (financial services), banking and management etc... are good examples of this. One may need to do post graduation in these specific subjects like MBA, MCA, etc... In industry like software, physics graduates are much valued manpower due to analytical abilities they acquire while doing their graduation. In fact, game physics has emerged as an important area which is important for those developing computer games and programmes like driving and flight simulation.

Teaching is another area where physics graduates and post graduates are expected to have extraordinary career in time to come due to Information and Communication Technology-based education that is likely to take over.

Government services like public service (like IAS, IPS...) and allied services like banking, railways and public sector companies do recruit physics graduates and post graduates. All these jobs require people with good analytical and problem-solving abilities and not merely those who have passed their exams. Students who are careful in preparing themselves through physics can have a career equally challenging, rewarding, and satisfying as any engineer, doctor or any other professional. Most of those who have done their gradutation in physics (B.Sc.) are found with very successful career in one of those fields described above. All what is required from students is focus on the career that they would want to pursue as a physics graduate. Success is bound to follow.