A Hearty Invitation to Physics Core Courses!

Dear I and II year students at IIT-Mandi:

A very hearty welcome to **Physics-Core-Courses** at IIT-Mandi!

Physics Core Curriculum at IIT-Mandi will consist of a total of 11 credits.

PH101 : Foundations of Classical Mechanics
(3 credits lecture course in the 1st semester)
PH101P: Physics Laboratory 1
(1 credit lab course in the 1st semester)
PH102: Foundations of Electrodynamics
(3 credits lecture course in the 2nd semester)
PH102P: Physics Laboratory 2
(1 credit lab course in the 2nd semester)
PH201: Methods of Contemporary Physics
(3 credits lecture course in the 3rd semester)

In the 'August-December, 2010' semester, the courses PH101 and PH201 will be offered, respectively to the 1st and 3rd semester students. PH101 will be offered by PCD, and PH201 by Dr. Hari R.Varma, Dr.Prasanth Jose and Dr. Bindu Radhamany.

These are amongst the most favorite courses of the Department of Physics! We trust that you will find the scope of these courses to be absolutely fascinating! These courses have been very specially devised for you.

PH101 would begin, but only barely, with something that you already know, such as Newton's laws. Very quickly – perhaps in the very first lecture hour – we shall move into unexplored terrain, and find our way through an exciting path that would lay very strong foundations to learn advance topics in physics and engineering.

We shall begin PH101 with something you already know: Newton's I and II laws. As you know very well, the heart of Newton's II law is encapsulated in the 'linear response' of a mechanical system to a stimulus, viz. the effect (acceleration) is proportional to the cause (force/interaction), expressed as $\vec{F} = m\vec{a}$. Now, if one puts $\vec{F} = \vec{0}$, will it be appropriate to conclude that $\vec{a}$ being zero, Newton's (first) law of inertia follows as a direct consequence of the second? If yes, why should we learn *three* laws at all, when it is trivial to derive one of them from the other? We shall seek clear answers to such fundamental concerns.

Subsequently, we shall recognize the principle of conservation of momentum inbuilt in Newton's III law, and immediately proceed to *reformulate* this law as a consequence of translational invariance in homogeneous space. This alternative approach places the conclusions of Newton's III law on a completely different footing, completely outside the domain of Newtonian mechanics! The method we adopt in fact illustrates an exciting path of actually discovering laws of nature, using invariance/symmetry principles.

We shall then discuss a fascinating question: Are the conservation principles consequences of the laws of nature? Or, are the laws of nature consequences of the symmetry principles that govern them? Following the work of Albert Einstein, Emmy Noether and Eugene Wigner in particular, we have learned that symmetry and invariance principles play an extremely fundamental role in contemporary physics. This approach is an important tool in the discovery of the laws of nature. We shall outline this approach using only elementary ideas that stem from Newtonian mechanics, and somewhat more lucidly from the 'alternative' framework of classical mechanics that is embodied in the 'principle of variation', developed in Lagrangian and Hamiltonian formulations. The central ideas in this discussion fall within the scope, of the celebrated Noether's theorem, and even if only in a remote way connects to PCT/Lorentz invariance of the 'standard model' of physics, search for the Higgs boson in the LHC experiments etc. This approach hooks up elementary ideas from the *first* course in Physics to contemporary research in frontiers areas, even if the intermediate links are challenging. Isn't that really wonderful? Mind you, even as we shall share the excitement of the Noether's theorem, our discussion will remain very much within your comfortable reach! Our discussion will be cast within the framework of familiar ground, by raising questions such as: other than energy and angular momentum, what else is conserved in the classical Kepler two-body problem?

In your second semester, you will take PH102: Foundations of Electrodynamics. Again, we shall begin with something you know already, such as the Coulomb's law, but immediately raise critical questions: to what level of confidence do we know that the force between charged particles varies as the inverse square of the distance between them? It turns out that the answer to this question is intimately related to the accuracy with which we know the rest-mass of the photon. We shall work with charges at rest and in motion, and walk the path that led Einstein to arrive at the special theory of relativity by examining the relative relationships between physical effects that occur when a conductor is physically moved relative a magnetic field, or a magnetic field is altered in the region where the conductor is held fixed. We shall work with electromagnetic potentials $(\phi, \vec{A})$ and with the fields $(\vec{E}, \vec{B})$ and develop confidence in the techniques of rigorous vector calculus which connects the potentials and the fields. More importantly, we shall search for insights in the physics of potentials and fields and discover that their mutual relationships are not merely a matter of mathematics, but have profound impact on the underlying physical principles. These principles will prepare us for their stunning exploitations for energy storage, conservation and transportation, and production of devices and gadgets that engages modern life-style so heavily with ever-advancing technology. We shall meet the flavor of modern technology in both PH101 and PH102 courses so that we shall speed ourselves into both modern applications of physical principles as much develop insights in physical principles to appreciate fascinating developments at the very frontiers of research in physics.

In the two courses PH101 and PH102, we shall emphasize that 'observation' and 'measurements' play a fundamental role in Physics. You would have heard that the 'father' of experimental physics, Galileo, described mathematics as the very language of physics. We shall introduce mathematical methods as and where needed, but keep the focus on physical principles. The course will begin with a discussion on just 'what constitutes the mechanical state of a system', and how to pose and solve the problem of the 'evolution' of the mechanical system. The courses PH101 and PH102 will be covered each in 10 Units (appended below). To be able to break new ground in science and technology, scientists and engineers both would gain from a robust foundation in Physics. It shall be our endeavor to provide that. **The courses will be dense; you are advised to work very hard, absolutely from *day 1.***

In the courses PH101P and PH102P, we trust that you will enjoy the laboratory sessions. We expect you to discover that laboratory experiments are a matter of great joy; you go well beyond 'data acquisition and processing'. You will be offered training on how to discover physical principles from careful and precision observations, and how to set up new experiments to gain further insights in the laws of nature. You will use the laboratory courses to discover the paths of Galileo and Raman, and learn to device and use tools to explore the physical world around you.

The course PH201, which you will take in your III semester, is specially tailored for you: engineering students. You will have acquired a sound foundation in the elements of classical mechanics, but only to discover that the classical description of the state of a mechanical system by 'position' and 'momentum' does not withstand the crucial scrutiny by a measurement process, fundamental to physical sciences. Since one cannot escape from the consequences of the interaction between a probe and the target whose physical properties are being measured, some of the 'original' properties of the target are lost during the interaction of the probe and the target. The result is that an UNCERTAINTY results in the simultaneous acquisition of information regarding 'position' and 'momentum', thus necessitating a new approach to describe the mechanical state of a system and study its temporal evolution. This new formalism is 'quantum mechanics', and *ALL* physical laws are consistent with it. Modern developments in science and technology – from GPS communication to nano-science to quantum computers require a thorough understanding of quantum mechanics. PH201 is designed to provide a preliminary and systematic acquaintance with the methods of contemporary physics. It would begin with the principles of quantum mechanics, discuss how statistics enters physical analysis of mechanical systems, and introduce you to some applications in atomic, molecular, condensed matter and nuclear physics.

We do look forward to get to know very many amongst you at a personal level as we shall together rediscover the romance in physics, beauty in its simplicity, and rigor in its formulation.

Yours sincerely,

- P. C. Deshmukh
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