Fall 2016, Mystery of Matter: PHY 313 and CEI 544
When: Wednesday 5:30-8:30PM
Where: Melville Library, E4315

Who: Prof. Abhay Deshpande, C-102, Department of Physics & Astronomy
       Aided by Dr. Nils Fege, Research Assistant Professor, Dept. of Physics and Astronomy
Office Hours: Walk-In knock on the door, or by appointment
(abhay.deshpande_at_stonybrook.edu)

This class will introduce physicists and non-physicists the tools and techniques of exploration matter through historically correct stories and anecdotes. It will present the evolution and our current understanding of the basic constituents of matter through logical arguments consistent with our understanding of matter at those times. At each of the milestones we will also try to see how the tools developed for science affected various aspects of the contemporary society. This journey of discovery will take us from the discovery of atoms, and its constituents, inner structure of protons and nuclei, the role of various fundamental processes in nature in realizing nuclear energy, birth and death of stars and galaxies. Towards the end we will discuss to most recent discoveries of dark matter/energy including the discovery of gravitational waves confirming the prediction by Einstein in 1916. When we discuss the quarks, gluons and phases of matters, we will visit the Relativistic Heavy Ion Collider (RHIC), a premier tool to study their interactions, located at Brookhaven National Laboratory (Upton, NY). In a nutshell, this course is intended to inform you of the basic fundamental quest of the humans to understand "where did
we come from and where are we going?” and have such discussions with friends, family, and further convince yourself that anyone with a systematic approach can ask good questions about science. Historical discoveries and their place in social and political institutions of the time will be presented and discussed, along with the issues of government funding and cost to the society. -- How will you use it?

Pre-requisite: U3 or U4 standing in non-physics/astronomy majors; one D.E.C. E or SNW course. While this course is not intended for physics and astronomy majors with U3 or U4 standing, all physics and astronomy majors can attend after an explicit permission to enroll from the instructor. Please contact Prof. Abhay Deshpande.
Learning Objectives

This course is intended to introduce and explain at a quantitative level the progress physics has made during the past century in understanding the way in which the Universe works. We will surpass “common sense” understanding each of us has learnt through our five senses by exploring how the concepts of modern physics were discovered, what they mean, and how they impact our every day lives.

We will try to cover the following topics:

Quantum Mechanics: How all things carry seemingly contradictory properties, of being waves and particles. Why is a bound system of particles, such as electrons trapped by proton or neutron residing in a nucleus, like notes on a musical instrument? How can particles leap forbidden regions to appear unscathed on the other side?

Radioactivity and Nuclei: What is inside atoms? How are atomic nuclei built from protons and neutrons? We will see what nuclear radioactivity consists of, how it works, and ways in which we can put it to good (and bad) use. We will see what quarks and gluons are, and how they co-existed in a quark gluon plasma when the Universe was a lot hotter and smaller.

Particle Physics: What kind of subatomic particles exist and how they fit together to make our world. We will talk about the Large Hadron Collider and the search & discovery of the Higgs Boson.

Neutrinos: The measurement of neutrinos coming from the sun, and how the puzzle of the missing solar neutrinos was solved. How we finally figured out that the particles, long thought to be massless, do in fact have mass after all.

Antimatter: What it is? How do we know it exists? How were antiparticles discovered experimentally and what’s being studied now?

Stars: What are stars made of up and how do they work? The stellar life time: from its birth to death to rebirth. We will also talk about supernovae and black holes.

String Theory: What is it all about? What can it tell us about our universe? Or any other?

Special Relativity: Experience of time is not absolute! It varies with the velocity of the observer. We will think about this statement and ask why the light speed is the ultimate speed. What limits does this pose to us as a society, and future space travel?

Harvesting the energy in nuclei: Nuclear reactor, nuclear bomb, nuclear medicine, radioactive dating
Technologies: We will see how modern technologies help and affect the society.

The Players in this Class:

Looking through a microscope:
If you look at matter very closely, we see its made of "Atoms", bound system of electrons orbiting charged positive nucleus. Looking more closely, we see inside the nucleus, we find protons (positively charged) and neutrons (neutral). How are they held together? Inside the protons and neutrons, reside Quarks and Gluons. We have not yet seen their substructure. We think they are fundamental particles, just like electrons, muons and tauons.

Looking through a telescope:
If we turn the microscope around and look at long distances and large scale objects in our universe, we see stars and galaxies... all the way to the edge of the galaxies. These days we know there is “stuff” that we can not see, but we know for sure it exists, called the Dark Matter (DM), and Dark Energy (DE). How are the visible stars and galaxies formed out of quarks and gluons and electrons (and muons?). And what is the nature of DM and DE?

In this course, with discussions about historic perspectives and some contemporary knowledge, we will learn how to ask questions and how science is done.
Lectures and Homework

Most material for this course can be found on the Web. The links below represent specific material that will be covered in the lecture.

August 31, 2016
Lecture 01
Introduction to the course, organization and planning

September 7, 2016
Lecture 02
- What are particles? What are waves? The electromagnetic waves and its spectrum.
- 20th Century: the wave particle duality, Young Double slit experiment, photo-electric effect, discovery of electrons
- Discovery of electrons and consequences of the discovery
- The periodic table of elements, Radioactivity, Rutherford’s experiment birth of modern subatomic physics
Mystery of Matter (Documentary) Episode 3
- Watch as homework & discuss next week in the class

September 14, 2016
Lecture 03
- Rutherford and Bohr: Atom at last
- Heisenberg’s uncertainty principle
- Davison and Germer experiment
- Introduction to Quantum Mechanics:
  - What is a “wave function”?
  - What are “quantum numbers”?

September 21, 2016
Lecture 04 Technology Enables Discovery
- Various particle detectors: Geiger, Cloud, MWPC, PMTs, Scintillators
- Discoveries of Cosmic Rays, Muons, Pions, Neutrons
- Binding energy per nucleon and stability of nuclei
- Unintended: Introduction to the fundamental particles of the Standard Model
Textbooks and useful material & Links

We will not follow any particular book. Most of the material can be found and researched on the Web. I will put interesting links associated with each lecture on the web page, but still the following books would be useful.

1) From Quarks to Cosmos (Leon Lederman & David Schramm Q2C)
2) Physics for Future Presidents by Richard Mueller (PFP)

Other useful books:
1) Thirty Years that Shook Physics by George Gamow
2) The Fly In The Cathedral by Brian Cathart
3) The God Particle by Leon Lederman and Dick Teresi
4) A Brief History of Time by Stephen Hawking
5) The Elegant Universe by Brian Green

Other Excellent Free Web Links:
1) HyperPhysics WebSite
2) How Stuff Works WebSite
3) Wikipedia WebSite
4) PBS Science and Nature
5) The New York Times (Science Section)
Grading

Attendance & participation: 20%
Attend class, and participate in the discussion. This is important, and most often in life, being there and participating in the happenings around you, is the first step, and most often half way to success. This is a small class, we expect many of the lectures to be full fledged discussions. Participation in those, is hence very important and beneficial to all.

Quizzes: 25%
These are intended to evaluate your grasp of the topics covered in previous lectures. This is important to assimilate the subsequent material and learn the process of thinking scientifically and systematically.

Homework: 25%
These may be reading assignments, or some time simple numerical problems associated with lecture material. If the current events are related to the discussions in the class, homework may mean reading up and researching some of those “current events” from newspapers, magazines and the web.

Final Presentation: 30%
There will be no final exam, but students are expected to work on a topic from the course they liked the most, or were intrigued by, research it and present it at the end of the year to the rest of the class including the teacher(s). They should also be able to defend the arguments they make in those presentations.
Academic Integrity:
Each student must pursue his/her academic goals honestly and be personally responsible for submitted work. Representing other person's work as your own is always wrong. Faculty are required to report any suspicious activity of academic dishonesty to the Academic Judiciary. For comprehensive information on academic integrity, including categories of academic dishonesty please refer to: University's web site on academic dishonesty.

Crisis Incident Management:
Stony Brook University expects students to respect the rights and privileges and property of other people. Faculty are required to report to the office of Judicial affairs any disruptive behavior that interrupts their ability to teach, compromise the safety of learning environment or inhibit student's ability to learn. Faculty at HSC school and the school of Medicine are required to follow their school specific procedures.