# Freshman Seminar 23p Phyiscs, Math and Puzzles Cumrun Vafa

**(Thursday 6:00-8:00, Jefferson-453)**

Physics is a highly developed branch of science with a broad range of applications. Despite the complexity of the universe the fundamental laws of physics are rather simple, if viewed properly. This seminar will focus on intuitive as well as mathematical underpinnings of some of the fundamental laws of nature, as well as how to appreciate the beauty of the laws. The seminars will use mathematical puzzles to introduce the basic features of physical laws. Main aspects discussed include the role of symmetries and their breaking in physical theories, the role of intuition as well as the power of modern math, including abstract ideas in topology, in unraveling the mysteries of the universe. The issue of why the universe is so big, as well as its potential explanation is also discussed. This seminar is recommended for students with a strong background in both math and physics and with keen interest in the relation between the two subjects.

# Course Syllabus

Week 1- General Introduction to modern physics

Week 2- Symmetry and conservation laws (puzzles: Time reversal symmetry, deck ordering, milk/water, domino chess, enter and exit a square grid, graph drawing without taking hand off paper )

Week 3- Symmetry breaking (puzzle: minimal road construction on a square)

Week 4- Power of simple and abstract math, examples include images of galaxies due to bending of light, temperature on equator, temperature and pressure on surface of earth (puzzles: chocolate breaking puzzle, number of games in a tennis tournament)

Week 5- Counter-intuitive math including modern examples arising from string theory (mirror symmetry, holography, geometric singularities) (puzzle: 3 box and a prize, points on a circle dividing the region inside, cutting through a regular size paper so you can go through it)

Week 6- Physical intuition, including how Newton and Galileo thought as well as bouyancy

Week 7- Counter-intuitive physics examples drawn from relativity (twin paradox) and quantum mechanics (light passing through objects)

Week 8- Naturalness in physics including power of dimensional analysis (puzzle: ‘Why a matrix satisfies its own characteristic equation?’)

Week 9- Unnaturalness and large numbers (math example: Counter example to Euler’s conjecture) cosmological constant, anthropic principle and string landscape

Week 10- Physics and Religion (where there is smoke, there is fire, or is there?) Week 11- Power of duality (puzzle: ants colliding on a stick)

Week 12- Summary of lessons learned

Assignments: Students are expected to do weekly reading as well as solving puzzles specifically introduced for the weekly discussions. They are also expected to participate in class discussions. At the end of the course, each student will choose one of the weekly topics and do a presentation on it.

# References

References for this course include the book “Puzzles to Unravel the Universe” written by myself (which will be provided for free) as well as readings from books written for general public as well as additional sources. In particular use will be made of Feynman’s Cornell Lectures, Brian Greene’s book, The Elegant Universe Susskind, The Cosmic Landscape: String Theory and the Illusion of Intelligent Design