

Semester and Year: Fall 2020

Stony Brook University  
Department of Physics and Astronomy  
College of Arts and Sciences  
PHY 684-30, (topics in Nuclear Physics) Nonperturbative QCD  
This course satisfies the DEC category N/A  
This course satisfies the SBC category TECH  
Course Instructor: Prof. Edward Shuryak  
Section: 01  
Office Hours: TBD  
Instructor contact information Edward.Shuryak@stonybrook.edu  
Homework grader TA, N/A.

Presentation mode: twice a week lectures, online/hybrid

#### COURSE DESCRIPTION:

##### *Course Topic*

This course is an introduction to fundamental theory of strong interactions, Quantum Chromo Dynamics (QCD). By “perturbative” we mean expansion in small coupling constant, via Feynman diagrams. The “nonperturbative” physics the course focus on is based on topological solitons, monopoles, sphalerons and instantons. These objects, described by semiclassical methods, play major role in changing the QCD vacuum state, via deconfinement and chiral symmetry restoration phase transitions, to Quark-Gluon Plasma phase.

Credits: 3

SBC: TECH

#### Introduction

1. Introduction: perturbative vs nonperturbative effects in QCD and other QFTs
2. Path integrals and semiclassical approximation in quantum and statistical mechanics
3. Topological landscape of gauge theories, Chern-Simons number, instanton paths and sphaleron configurations
4. Instanton ensembles in the QCD vacuum, Euclidean correlation functions and light-front wave function of hadrons
5. Sphaleron production in heavy ion collisions and cosmological electroweak phase transition
6. Nonabelian monopoles: the solution, dynamics, confinement and electric-magnetic duality
7. Fractional instantons or the instanton-dyons
8. Ensemble of instanton-dyons and QCD phase transitions
9. Duality between monopole and instanton-dyons
10. Nonperturbative quark interactions, hadronic light-front wave functions and formfactors

##### *Course Pre/co-requisites*

Graduate level courses on quantum mechanics and statistical mechanics

#### COURSE LEARNING OBJECTIVES:

Introduce students to modern trends in Theoretical Nuclear and Particle Physics.

#### COURSE REQUIREMENTS:

*Attendance and Make Up Policy: lectures to be given online at fixed times, but also recorded.*

*There will also be online one-on-one discussions (office hours). Time to be defined*

##### *Grades*

*Along the course there would be numerous exercises offered, and discussed.*

*Those are required or included in grades*

*The final exam will take the form of a series of mini-lectures by students at the end of the semester.*

*Assigned presentations will be selected from the topic list to be provided.*

bibliographical list of readings:

**There are no textbooks on the topic yet, but the material is covered in complete lecture notes to be provided to students. Its preliminary version can be seen in:**

- **Lectures on nonperturbative QCD ( Nonperturbative Topological Phenomena in QCD and Related Theories)** e-Print: 1812.01509, v2

**Student Accessibility Support Services (SASC):**

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Student Accessibility Support Center, ECC (Educational Communications Center) Building, Room 128, (631)632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential. <https://www.stonybrook.edu/commcms/studentaffairs/sasc/facstaff/syllabus.php>

**Academic Integrity Statement:**

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at:

[http://www.stonybrook.edu/commcms/academic\\_integrity/index.html](http://www.stonybrook.edu/commcms/academic_integrity/index.html)

**Critical Incident Management Statement**

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.