PHY501 Classical Mechanics

Professor Alexander Abanov

PHY 515 • ADVANCED LABORATORY

Three experiments. Three fields. Hands-on research.

Work in groups of two and take each investigation from apparatus to a publication-style report.

AMO

CONDENSED MATTER

HEP / NUCLEAR

ONE EXPERIMENT IN EACH AREA

4 WEEKS

8 lab sessions per experiment

EACH EXPERIMENT IS A COMPLETE RESEARCH CYCLE

01 **Set up**
equipment

02 **Plan & conduct**
measurements

03 **Analyze**
data in detail

04 **Evaluate**
uncertainties

05 **Write**
publication-style report

CLOSE MENTORING

Work closely with an instructor throughout each four-week experiment.

AI USE

Discuss use of AI with instructor.

WAIVERS

Possible waivers must be discussed and approved in advance.

Math Lab

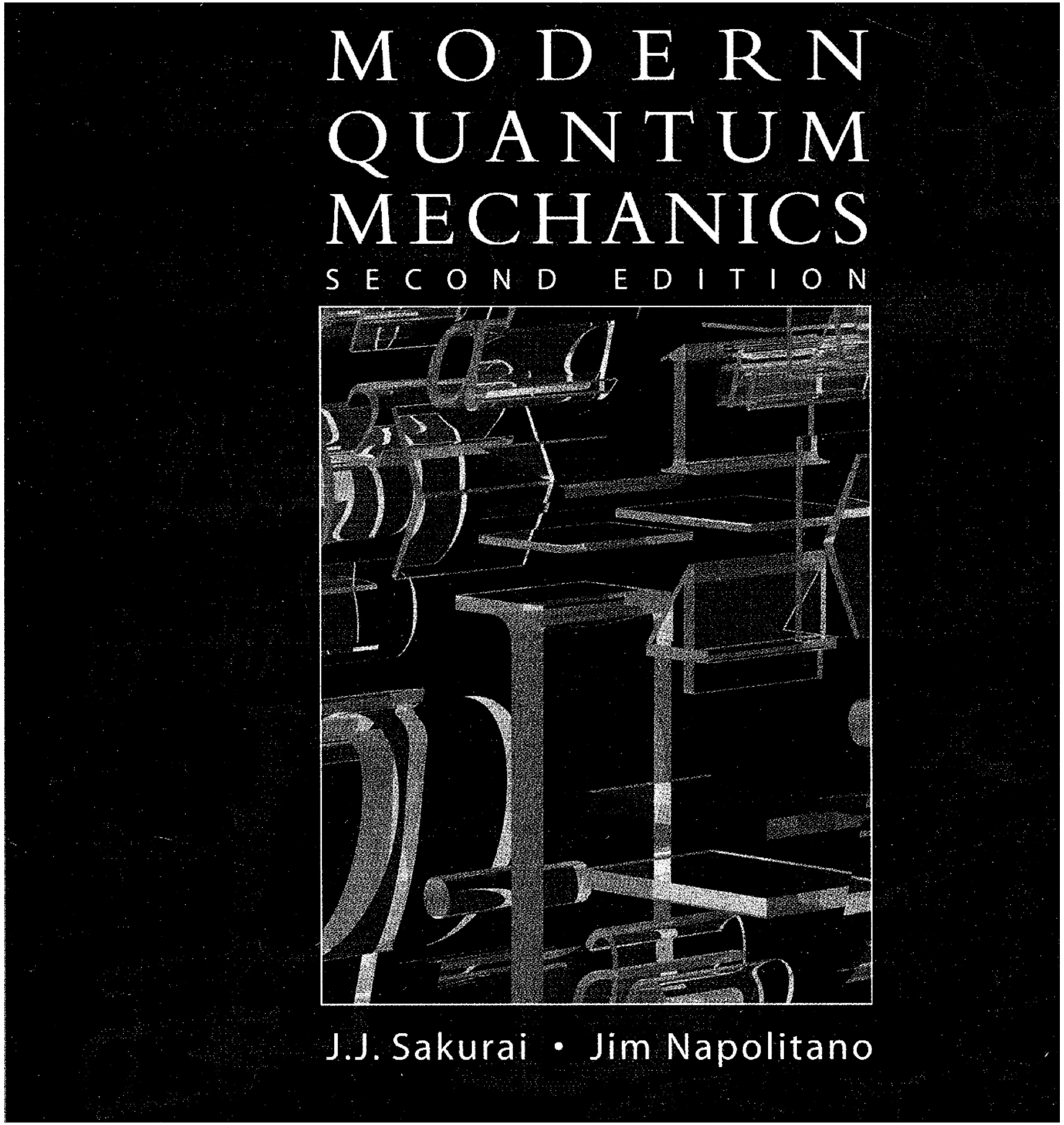
- Modular, unofficial class: come to some, no registration needed
- Wednesdays, 12:30pm - 1:50pm, P118
- Teachers: Sergey Syritsyn, Derek Teaney, Sasha Abanov, Paul Goldbart

Week 1: **Series Expansions**
Week 2: **Matrices**
Week 3: **Eigenvalues & Eigenvectors**
Week 4: **Calculus of Variations**
Week 5: **Vector Calculus I**
Week 6: **Vector Calculus II**
Week 7: **ODEs**

Week 8: **Special Functions**
Week 9: **Fourier & Integral Transforms**
Week 10: **PDEs I**
Week 11: **PDEs II**
Week 12: **Green's Functions**
Week 13: **TBD**
Week 14: **OPEN for questions**

PHYSICS 511 QUANTUM MECHANICS

- **Lectures:** Tuesday Thursday 11:00 am - 12:20 pm, P-113 Physics Bldg.
- **Textbook:** J.J. Sakurai and Jim Napolitano, ``Modern quantum mechanics"
- **Supplementary reading:** L.D. Landau and E.M. Lifshitz, ``Quantum mechanics'',
  R. Shankar, ``Principles of quantum mechanics''.
- **Approximate outline:**
  1. Basic concepts: Hilbert space, quantum dynamics, measurements, using as an example two-state quantum systems. Elements of quantum information.
  2. One-dimensional problems.
  3. Angular momentum, spin.
  4. Symmetries in quantum mechanics.
  5. Hydrogen atom.
- **Grading:** Homework 30% , Midterm 30% , Final 40% .



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Physics 540: Statistical Mechanics, Fall, 2026

Instructor: Prof. R. Shrock, email: robert.shrock@stonybrook.edu

Tue.-Thu. 9:30 - 10:50 AM, Staller 3220
Office hrs. - by appointment; use email.

Recommended preparation: an undergraduate course in statistical mechanics

Textbook: The course will mainly use lecture notes and free online information resources. Although we will not follow any one textbook closely, a useful auxiliary book is H. E. Stanley, *Phase Transitions and Critical Phenomena*.

Course requirements are: homework, midterm, final exam, and class participation, weighted as follows: homework: 25 %, midterm: 30 %, final exam: 40 %, class participation: 5 %.

This course will coverstatistical mechanics, including topics in the list below:

- General thermodynamics and statistical ensembles.
- Phase transitions and critical phenomena: examples with liquid-gas-solid systems and magnetic systems; experimental data; phase diagrams; order of transition; critical singularities in thermodynamic functions.
- Analysis of some models, including Ising, q-state Potts, O(N) vector models; exact solutions for 1D cases; transfer matrix method.
- Ginzburg-Landau theory and mean field theory.
- Modern theory of second-order phase transitions: renormalization group (RG); universality classes and critical exponents; scaling relations.
- Approximate methods: high-temperature and low-temperature series expansions; low-density series expansions, Padé approximants.
- van der Waals and other equations of state; superheating and supercooling.
- Monte Carlo simulations.
- Quantum statistics: Fermi-Dirac and Bose-Einstein distribution functions and applications to phonons, photons, Bose-Einstein condensation; superconductivity and superfluidity.

If time permits, the course may cover some additional topics, including topological phase transitions, liquid crystals, orientational ordering, percolation transition, and the Lee-Yang-Fisher complexification program.

Learning goals: Students will gain (i) an understanding of the principles and methods of modern statistical mechanics (SM); (ii) familiarity with models used in SM; and (iii) a working knowledge of applications of SM.

PHY503 Mathematical Physics

Professor Sergey Syritsyn

PHY514 Research Instruments

Professor Harold Metcalf

PHY517 Astronomical Techniques

Professor Simon Birrer

Collaboration of SBU & BNL

Established
November 19, 2008

Educating the Next Generation of
Accelerator Physicists and Engineers

CASE
Center for Accelerator Science and Education

The goals of CASE are:

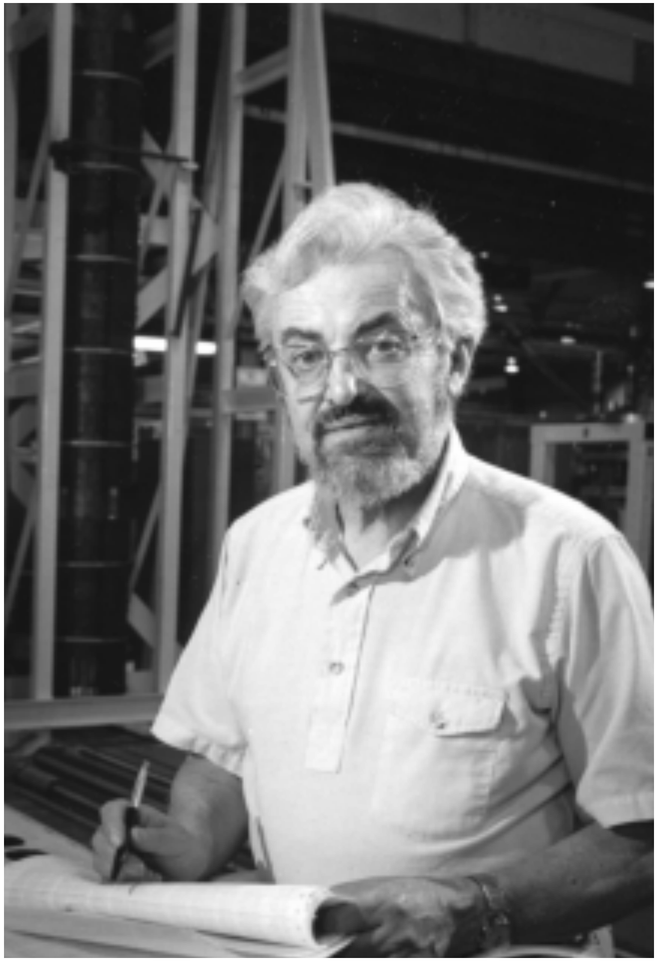
- To train scientists and engineers with the aim of advancing the field of accelerator science;
- To develop a unique educational program that will provide broad access to research accelerators;
- To expand interdisciplinary research and education program utilizing accelerators.

The Accelerator Base

- BNL has the largest assembly of advanced accelerators in the U.S. engaged in a broad spectrum of sciences;
- An Accelerator Test Facility has a national user program in accelerator research;
- Many outstanding BNL scientists already affiliated with and teaching at SBU.

http://case.physics.stonybrook.edu/index.php/Main_Page

Ernest Courant Traineeship in Accelerator Science and Engineering



- ✓ CASE (SBU & BNL), in collaboration with FERMI National Accelerator Laboratory operates the *Ernest Courant Traineeship in Accelerator Science & Engineering funded by High Energy Physics office of the US Department of Energy* – 10 years, $6.6M awards – we are starting Year 8

- ✓ DoE has specific interest in graduates with specialization in the following topics:
  - ✓ (a) Physics of large accelerators and systems engineering;
  - ✓ (b) Superconducting radiofrequency accelerator physics and engineering;
  - ✓ (c) Radiofrequency power system engineering,
  - ✓ (d) Cryogenic systems engineering (especially liquid helium systems).
- ✓ Students in the traineeship program who complete the necessary courses (12 or more credits in accelerator science and engineering) will be issued a Certificate in Accelerator Science and Engineering with specialization in one of the seven areas.
- ✓ This traineeship is available for all students independent of citizenship. Funds provided by this DoE award can be used to provide two years of full support for students who are US citizens or US permanent residents.
- ✓ If you are interested in joining this traineeship contact one us: V.N. Litvinenko, N. Vafaei-Najafabadi or our research administrator: Avril Coakley

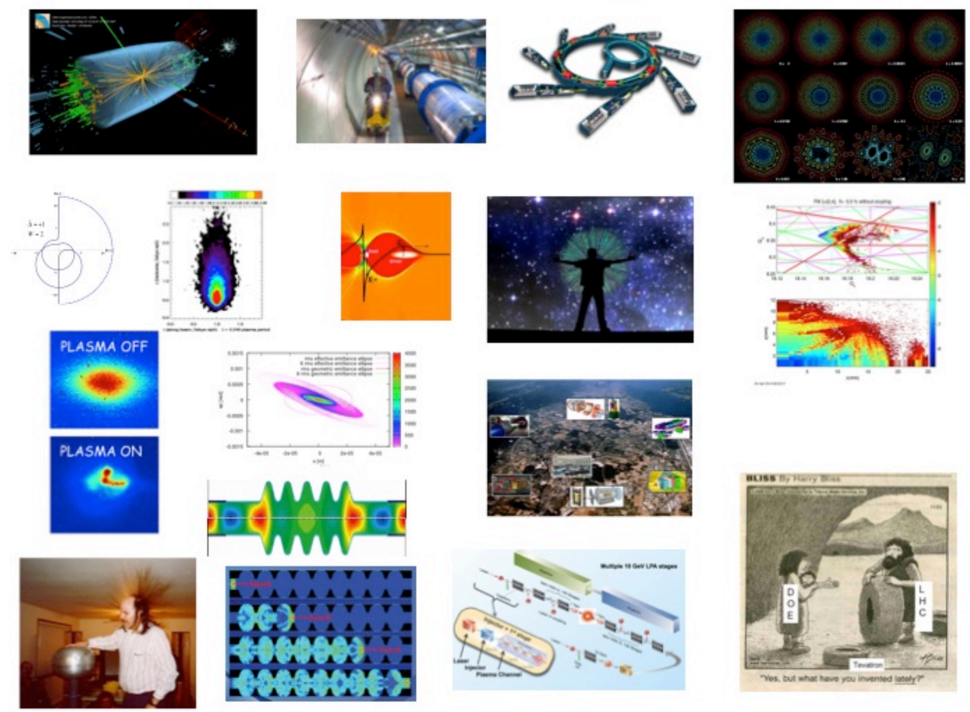
http://case.physics.stonybrook.edu/index.php/Ernest_courant_traineeship_main

Fall 2026, PHY 554
Fundamentals of Accelerator Physics

Yichao Jing

Jun Ma

Dmitry Kayran



- A glance into the history of accelerators.
- Approach the accelerators through solving equations of motion.
- Introduce various components in the accelerators
- Learn different accelerator's applications

This course could greatly benefit High Energy/Nuclear Physics students and those who are using synchrotron radiation – if you are curious what is on the other side of your apparatus

Detailed syllabus, goals and course structures are available online at CASE website. Lectures/simulations/Homeworks will be posted on course page:

http://case.physics.stonybrook.edu/index.php/PHY554_fall_2026

Physical & Quantitative Biology
BME / CHE / PHY 558

Fall 2026 / MWF 11:00 – 11:55 AM; in person, Laufer Center 101 https://laufercenter.org/ . Lectures will be recorded.

Recitations with TA: M. Londoño every Monday from 12:00 pm.

Weekly homework. Two midterms (October 14, November 23).

Gábor Balázsi, Course Coordinator: gabor.balazsi@stonybrook.edu

Big questions:

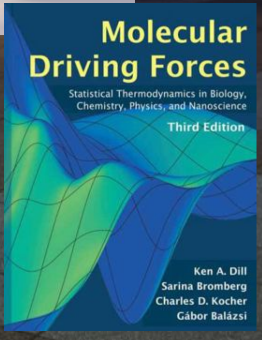
-Why are atoms so small? ("What Is Life?" by Erwin Schrödinger)

-Can you build a cell? Can you build a human? How does Nature do it? ("What I cannot build, I do not understand." - Richard Feynman)

Main textbook:

Dill, Bromberg, Kocher, Balázsi:

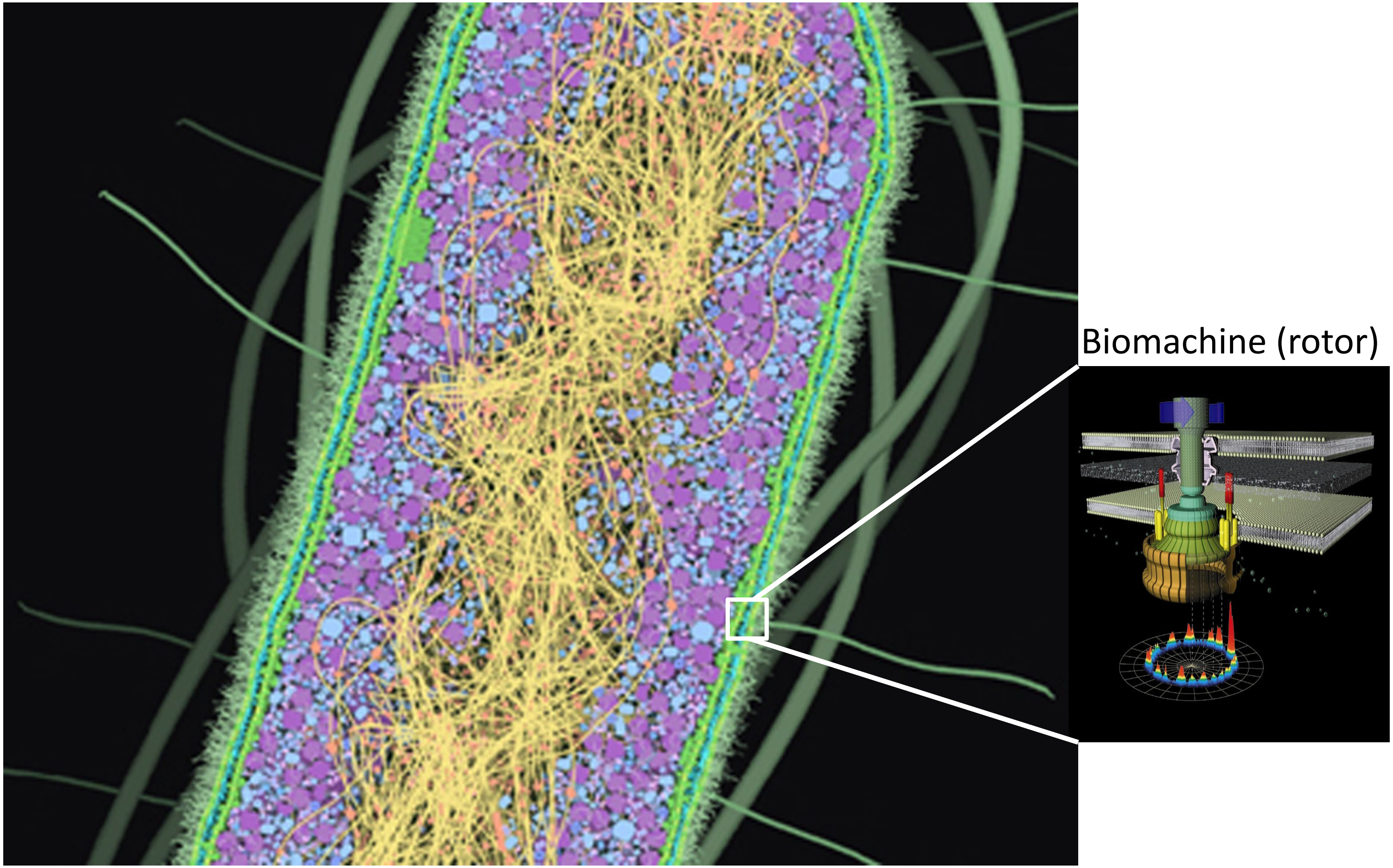
Molecular Driving Forces (3rd Edition, MIT Press, 2026)



Course goals

1. Describe physical "driving forces" of chemistry and biology (=far from equilibrium): <u>Free Energy and its applications.</u>
2. Build simple models, design biomachines, drugs, gene circuits, learn how Life works.
3. Join the physics crew that thinks about life:
   – Erwin Schrödinger, Leó Szilárd, John von Neumann, Max Delbrück, Roger Penrose, …

The interior of a bacterial cell



Biomachine (rotor)

Goodsell David S. (2009) The Machinery of Life. 2nd edn. Copernicus Books, New York.

"Ask not what you can do for biology, but what biology can do for you." (N. Goldenfeld)

PHY555 Solid State I

Professor Paul Goldbart

PHY560 Frontiers of Physics and Astrophysics

Professor Barry Barish

PHY562 Lasers and Modern Optics

Professor Tom Weinacht

PHY568 Quantum Information Science (QIS)

Lecture time: 2:00-3:20PM Monday & Wednesday (SOCBEHAV SCI S218)
Instructor: Nathanan Tantivasadakarn and Tzu-Chieh Wei

Course description:
This is a survey of the fast-evolving field of quantum information, ranging from Bell inequality, quantum teleportation to quantum algorithms and quantum programming frameworks. It aims to cover the essential knowledge of quantum information science and helps to bridge the gap to the current research activities of the field. Emphasis will be placed on solid-state platforms of quantum computers, topological error correction codes, and applications. Other systems will be introduced when necessary. Some illustration of quantum programming will be done on IBM's transmon-type cloud quantum computers.

Pre-requisite: Quantum Physics; or concurrent registration of Quantum Mechanics I

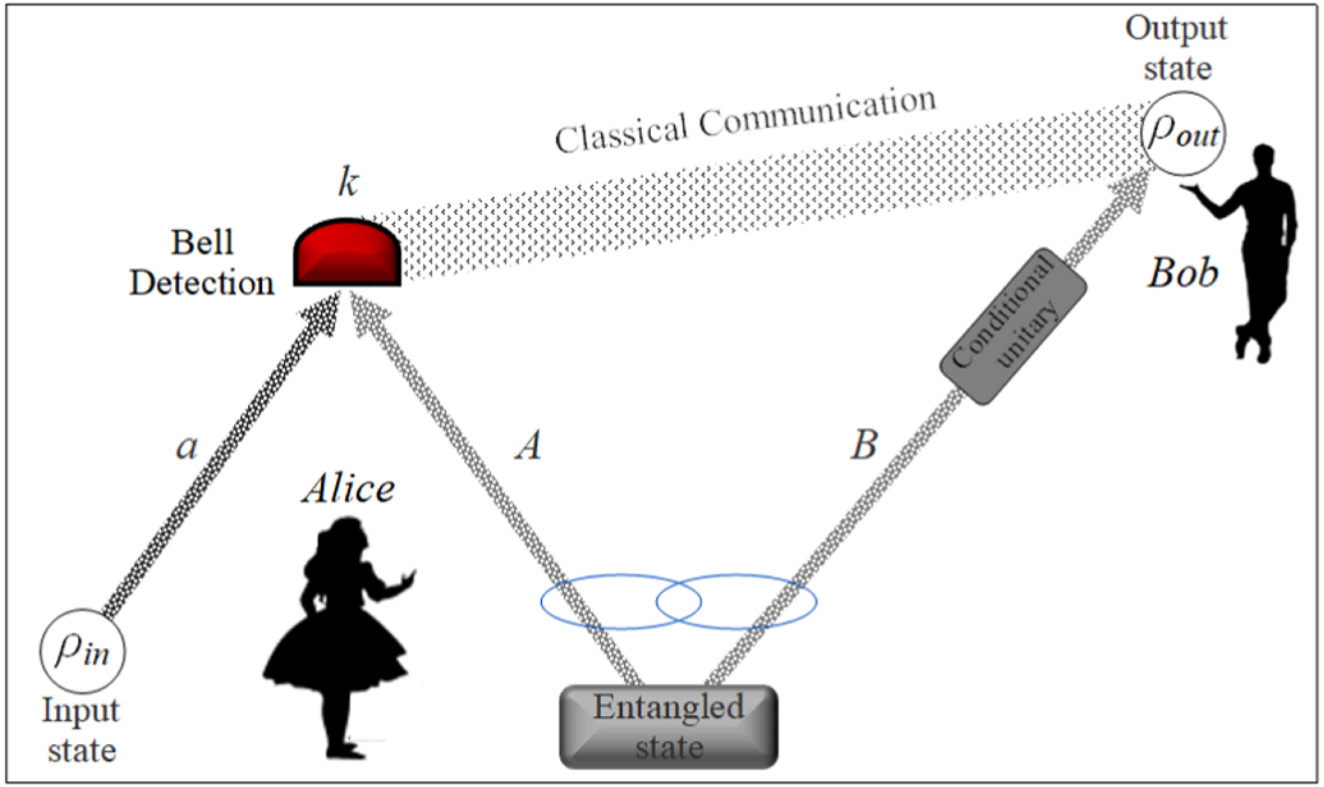
QIST Master's Curriculum Design

Two Focus Areas:	(I) Quantum Information Theory & Programming (QITP)		(II) Quantum Technology Hardware and Materials (QTHM)
Core courses: (9 credits)	**PHY 568 Quantum Info. Science***	**PHY 631 Physical Systems and Materials for QIP**	**PHY 569 QIST Laboratory**
Focus area courses (3 credits)	**PHY 605 Quantum Programming** **PHY 680 (Advanced topics in) Quantum Computing**		PHY 611/612 Quantum Electronics ESE 511 Solid-State Electronics ESE 515 Quantum Electronics I
Electives: (minimum 12 credits; at least one from non-PHY)	**ESE 512 Intro. to Quantum Systems Engineering** **CSE 550 Quantum Computing and Applications** PHY 511/512 Quantum Mechanics I/II PHY 555/556 Solid State I/II CHE 521 Quantum Chemistry 1 CSE 505 Computing with Logics CSE 540 Theory of Computation CSE 613 Parallel Programming		ESE 538 Nanoelectronics ESE 519 Semiconductor Lasers and Photodetectors PHY 514 Research Instruments PHY 515 Methods of Experimental Research PHY 562 Lasers and Modern Optics PHY567 Theoretical Chemical Physics CSE 548 Analysis of Algorithms CSE 546 Cryptography
Research Project /Internship (6 credits)	**PHY 580 Special Research Projects Research**	**or**	**PHY 595 Master's Degree Thesis**

Minimum of 30 credits

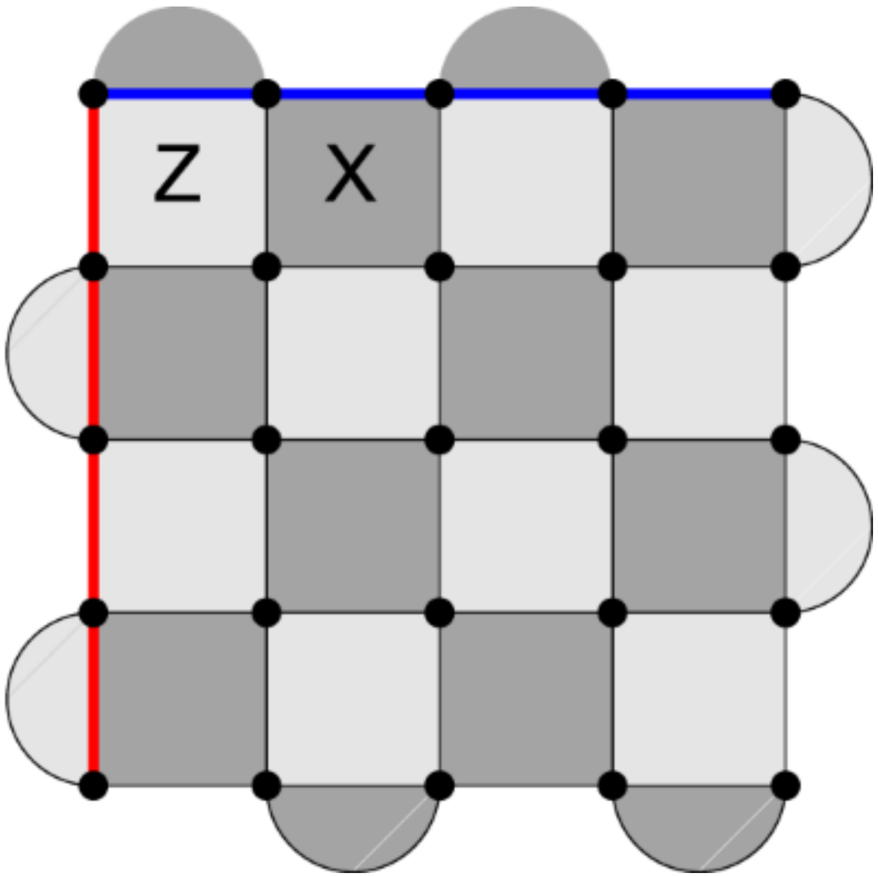
PHY 568 QIS Learning outcomes:

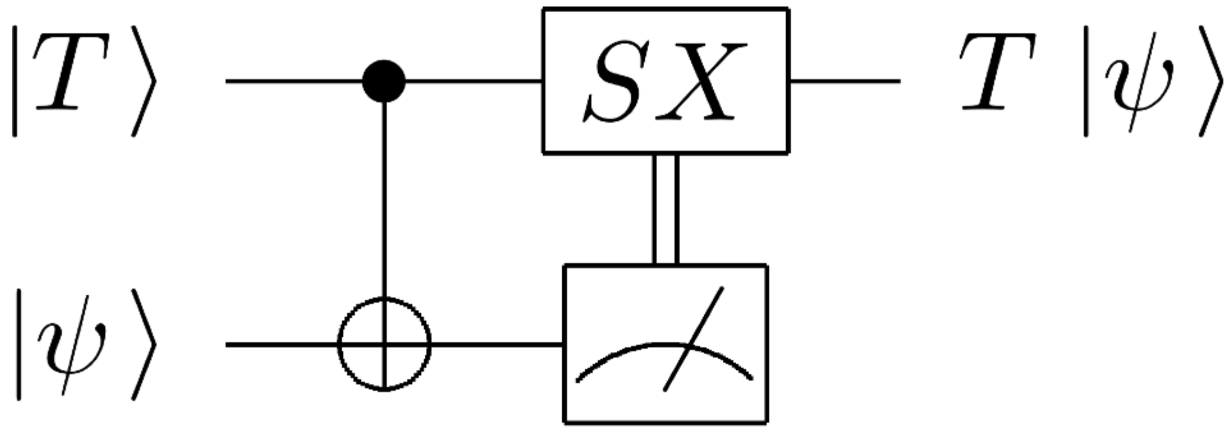
Understand the basics of **quantum information theory** and their relation to statistical mechanics and quantum entanglement



PHY 568 QIS Learning outcomes:

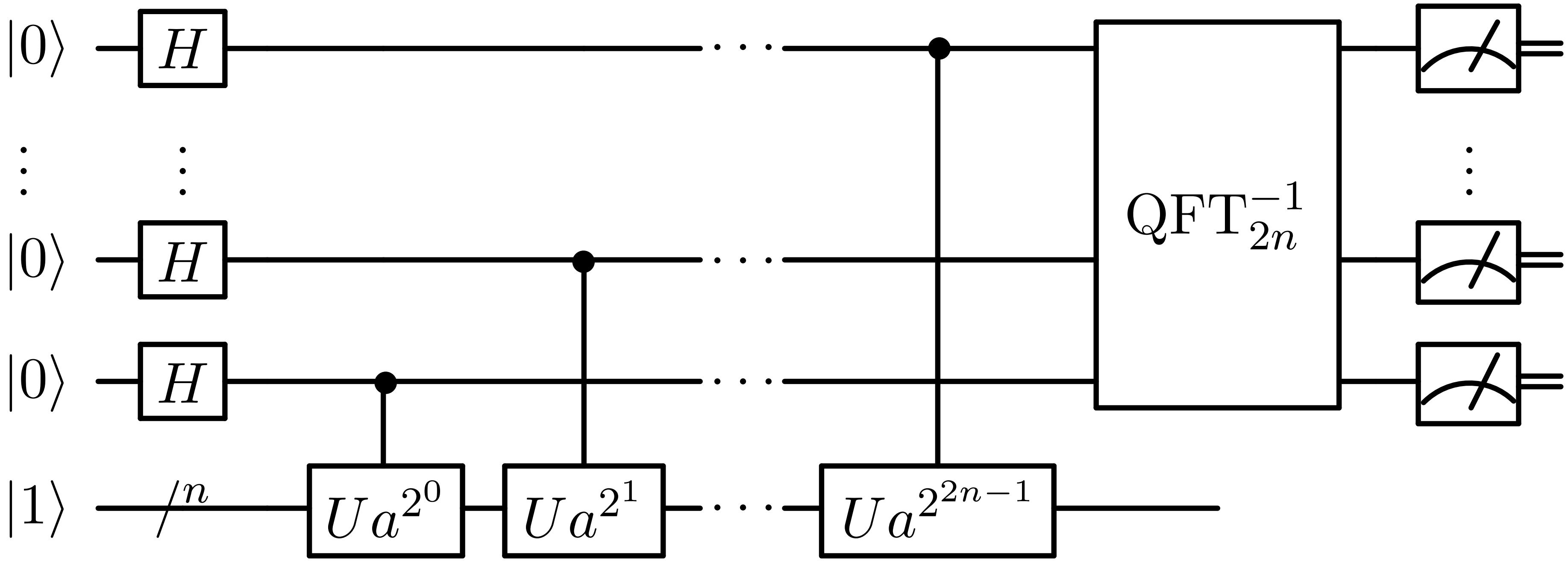
Understand the physical principles of **quantum error correction** and **quantum computation**





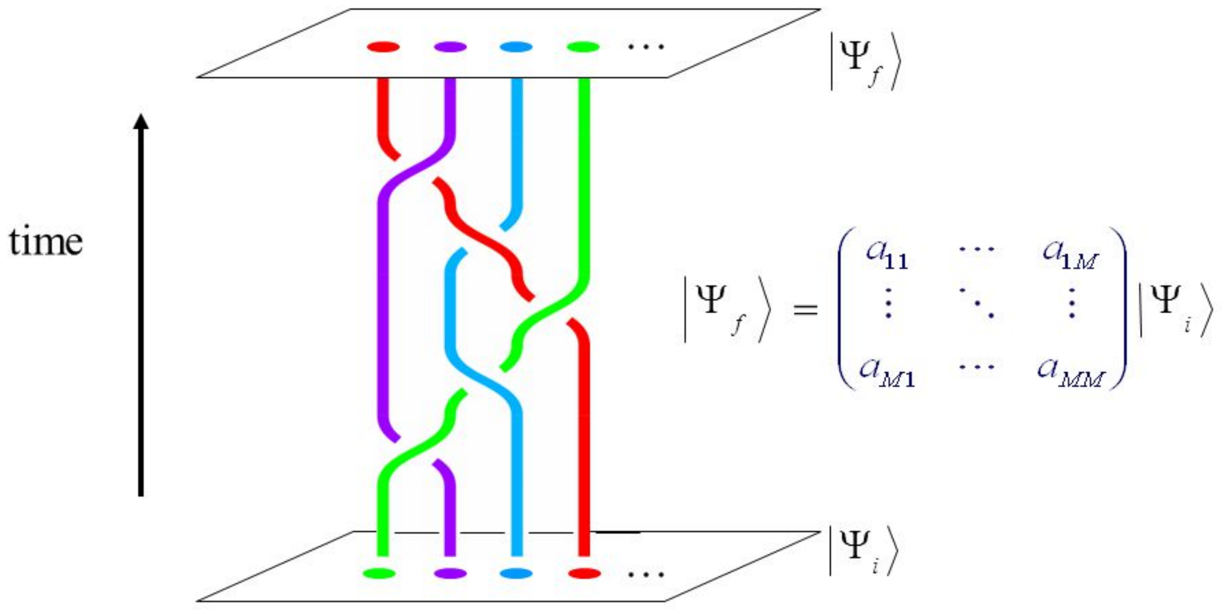
PHY 568 QIS Learning outcomes:

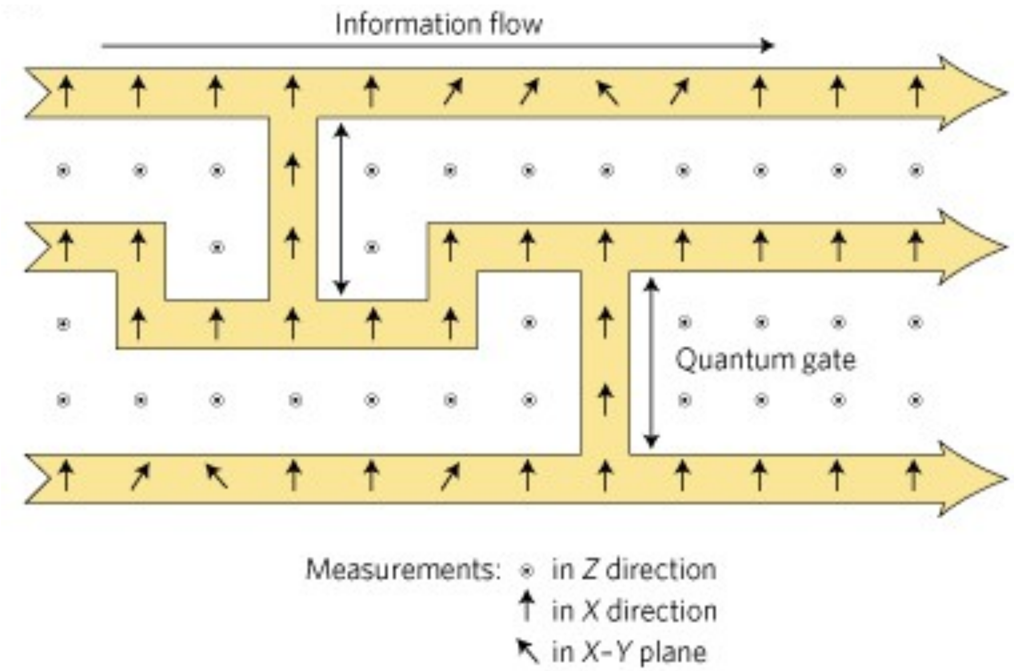
Understand how **quantum algorithms** work such as Shor's factoring algorithm and Grover's search algorithm



PHY 568 QIS Learning outcomes:

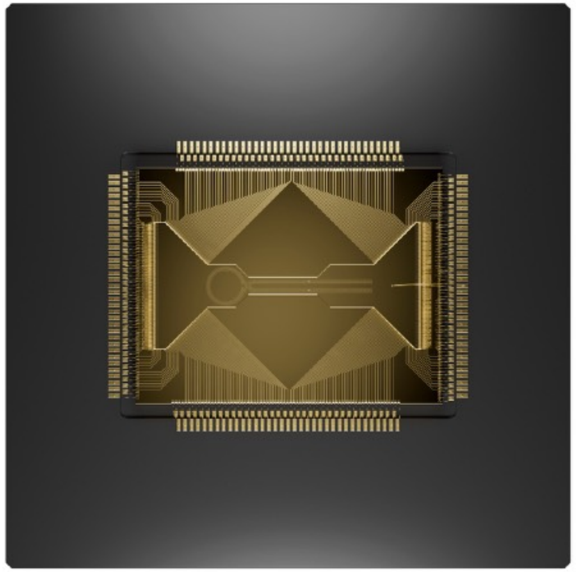
• Understand various **frameworks of quantum computation**, such as the standard circuit model, topological, adiabatic, and measurement-based quantum computation



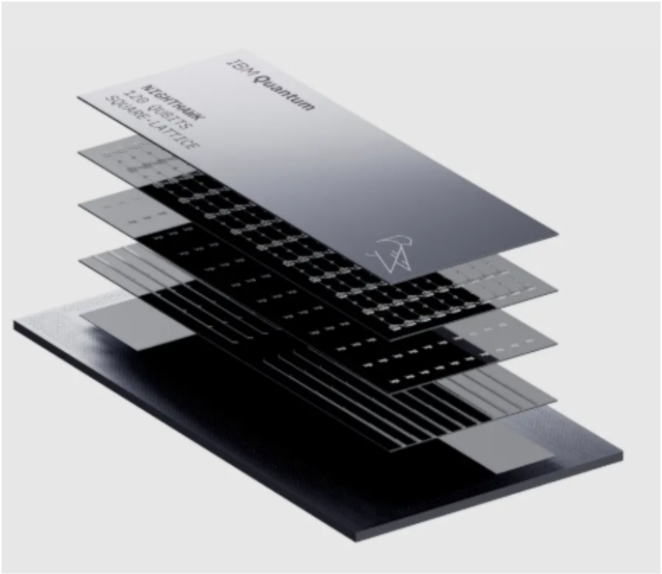


PHY 568 QIS Learning outcomes:

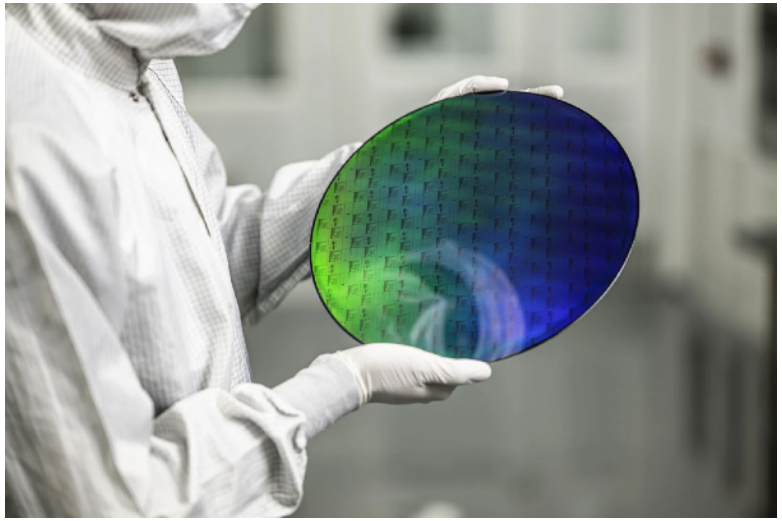
Understand the working principles of **qubits in various physical platforms**



Quantinuum Helios
(Trapped ions)



IBM Nighthawk
(Superconducting qubits)



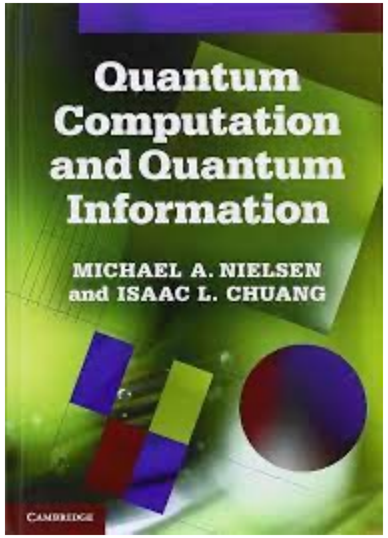
Psiquantum
(photonics)

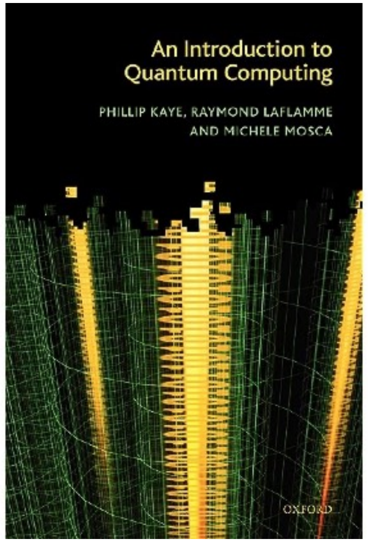
Textbooks?

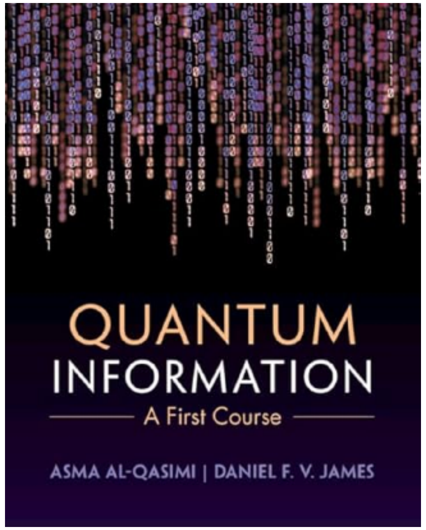
- ❑ Lecture notes from previous years by Prof. Wei are available on the course website

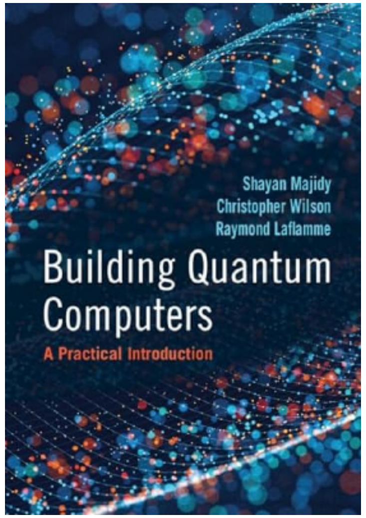
- ❑ Other recommended textbooks:

  Preskill's lecture notes: [Physics 219 Course Information (caltech.edu)]









Grading:

(1) Homework 50% [roughly one homework set every two weeks]

(2) Participation (extra 5%)

(3) Mid-semester exam 25%

(4) **Final presentation** 25%

Want a head start? 25 recorded lectures from 2020 PHY 682 (precursor of PHY 568) by Prof. Wei are on YouTube

PHY 611: QFT 2
Patrick Meade

This course will be a continuation of PHY610 by Professor Zamolodchikov. You are welcome to take it if you have experience with QFT but didn't take 610. However you are expected to have a mastery* of scalar QFT, including Path Integrals,1 loop calculations and Wilsonian Renormalization, first lectures/HW should be a good normalization but contact me if you have questions!

Topics that will be covered in 611: Unitarity methods, Optical Theorem, Sum Rules, Higher spins and Little Group representations, Abelian/Non-Abelian Gauge Theories (quantization,renormalization,ghosts, BRST), IR divergences, Chiral Gauge theories, Anomalies, Spontaneous Symmetry Breaking

Structure of Course

The course will be a traditional lecture course with roughly 10 HWs over the semester, an in-class midterm and final.

No official text, but Schwartz, Srednicki and Weinberg QFT books will be heavily drawn on.

Two grading schemes (your grade will be the best of these 2):

HW 20%, Midterm 40%, Final 40% or HW 20%, Midterm 30%, Final 50%

Please email me (patrick.meade@stonybrook.edu) if you have any questions!

PHY612 Theoretical Particle Physics

Professor Rouven Essig

FALL 2026 • GRADUATE COURSE

PHY 620

Modern General Relativity

Neelima Sehgal • Department of Physics & Astronomy

astro.sunysb.edu/nsehgal/Site/PHY_620.html

- **Class times**

  Mondays & Wednesdays
  11:00 am – 12:20 pm, ESS 450

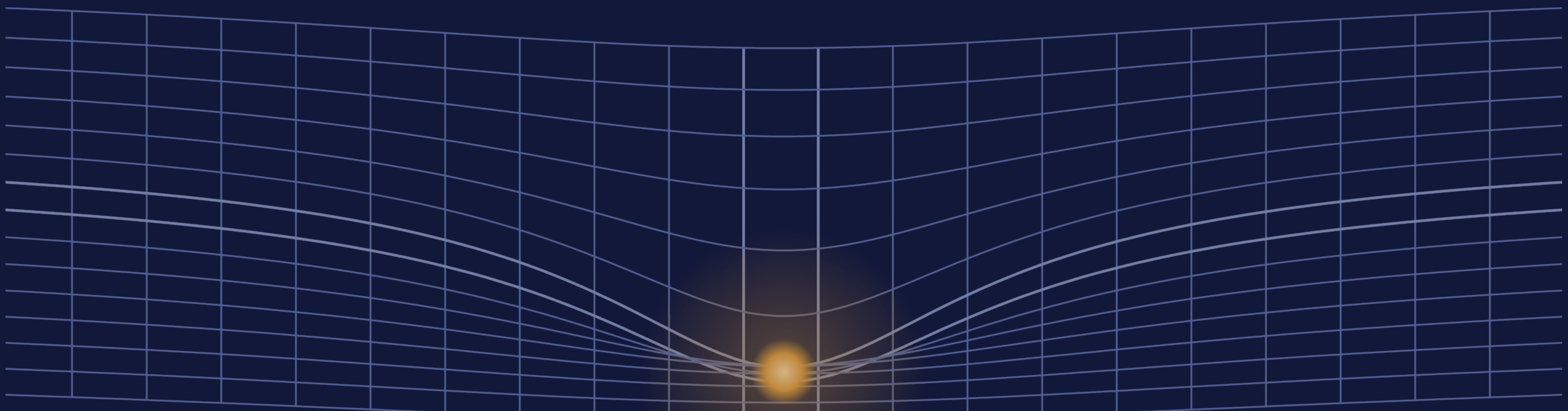
- **Office hours**

  Wednesdays 4:00 – 5:00 pm
  454 ESS

- **Contact**

  neelima.sehgal@stonybrook.edu

Text: Schutz, *A First Course in General Relativity* (CUP, 2022)



What we cover

Roughly one chapter of Schutz per week

- Vector and tensor analysis in special relativity
- Perfect fluids in special relativity
- Curvature and curved manifolds
- Physics in curved spacetime
- Einstein field equations
- Gravitational waves
- Spherical stars
- Black holes
- Gravitational lensing
- Cosmology

COURSE GRADE

Attendance & participation	10%
Homework problem sets	10%
Midterm I	25%
Midterm II	25%
Final exam	30%

Problem sets

Due Mondays 10 am
via Brightspace

Midterms

Wed 30 September
Wed 4 November

Final exam

Wednesday
9 December

astro.sunysb.edu/nsehgal/Site/PHY_620.html

Where it sits: the astronomy core sequence

Four courses rotate on a four-semester cycle — one per semester, each offered only once every two years

PHY 521	PHY 524	PHY 523	PHY 522
Stars	Cosmology	Galaxies	Interstellar Medium

EVERY 2 YEARS

PHY 620 **Modern General Relativity**

Can serve as a fifth astro course — offered every year

ANNUAL

For astrophysics or cosmology concentration: take any three of these five. Take each core course when it comes up — postponing one means waiting a full two-year cycle for it to come back around.

String Theory I (PHY 622)

by Martin Roček and Peter van Nieuwenhuizen

Mon & Wed 9:30 – 10:50 in the YITP common room

We start from scratch, and introduce in the fall semester the following four subjects:

- Bosonic string,
- Spinning string,
- T-duality,
- D-branes.

The requirements for this course are some basic quantum field theory (QFT) and some elementary General Relativity (GR). More in detail:

QFT: the actions for a real massless scalar field and for Maxwell theory ($\mathcal{L} = -\frac{1}{2}\partial_\alpha\phi\partial^\alpha\phi$ and $\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu}$); the canonical quantization of a scalar field in 4 dimensions, also its path integral quantization ($p = \frac{\partial}{\partial\dot{\phi}}L$ and $Z(J) = e^{\frac{i}{\hbar}S+\int J\phi d\sigma dt}$);

GR: general coordinate transformations of tensors in curved space; the Hilbert-Einstein action and its field equations.

Typed notes are handed out in class. There are weekly homework assignments, and (for those who are interested) the solutions to the homeworks are discussed every week in a special session.

At the end of the fall semester there is both a written and an oral "exam". (This "exam" is often an opportunity to discuss issues that were not clear to you even after study.)

We teach "interactively": questions are most welcome and you can come to our offices whenever you get stuck. Here is a detailed list of topics (they will all be explained, and none is assumed to be known).

Bosonic string.

1. Action ($\mathcal{L} = -\frac{1}{2}T\sqrt{-h}h^{\alpha\beta}\partial_\alpha X^\mu\partial_\beta X^\nu\eta_{\mu\nu}$)
2. Local worldsheet symmetries (E and W)
3. Rigid spacetime symmetries (Poincaré)
4. Field equations and boundary conditions in E-W gauge ($h_{\alpha\beta} = \eta_{\alpha\beta}$)

5. Mode expansions $\left(X^\mu(t,\sigma) = \frac{1}{2}\left(X_L(t+\sigma) + X_R(t-\sigma)\right)\right)$
6. Canonical quantization $([\alpha^\mu_m, \alpha^\nu_n] = m\eta^{\mu\nu}\delta_{m+n,0})$
7. Constraints $T_{\alpha\beta} = 0$ (the field equations of $h_{\alpha\beta}$)
8. Conformal symmetry and light-cone gauge $(X^+_{osc} = 0)$
9. Mass formula and spectra (open and closed)
10. Introduction to covariant BRST quantization (b, c, d)
11. Covariant BRST quantization of strings (open and closed)
12. Cohomology of open strings (gives same spectra as before)
13. Cohomology of closed string (gives same spectra as before)

Spinning string. The same topics as for the bosonic string, but also a gentle introduction to rigid supersymmetry and supergravity (= local supersymmetry).

T-duality and D-branes

1. Closed bosonic string on a compact space and winding modes
2. A symmetry of the spectrum and T-duality of the closed bosonic string
3. T-duality and the open bosonic string lead to D-branes
4. T-duality of the closed spinning string–Type IIA vs Type IIB
5. T-duality of the open spinning string and D-brane charges
6. T-duality of Ramond-Ramond fields

D-brane solutions in supergravity–I do not know how much of this will fit into the first semester

1. Strings in curved backgrounds
2. Low energy effective actions and supergravity
3. M-theory and 11D supergravity
4. M-theory BPS solutions

5. Dimensional reduction to D=10

6. D-brane solutions in type IIA

7. T-duality and D-brane solutions in type IIB

PHY655 Advanced Graduate Seminar

Professor Martin Rocek

PHY 680: Introduction to the Dynamics of Supersymmetric QFTs

Leonardo Rastelli

Tu–Th 11:00–12:20 · YITP seminar room, Math 6-125

A laboratory where the hard questions about QFT have exact answers

Supersymmetry as a laboratory

- **The problem.** Strong coupling is hard. Confinement, the phases of gauge theories, where an RG flow ends up — usually we can only guess.
- **The crutch.** Supersymmetry buys exact answers, with the dynamics still fully non-perturbative.
- **The payoff.** What we normally have to assume, here we can derive — notably dualities between theories that look nothing alike.
- **Why you care.** The lessons are general: part of what a theorist of any kind should know, whether or not you ever work on susy.
- **A bonus.** A spectacular source of modern mathematics.

The course

What we will cover

Susy kinematics — fast, just notation

Holomorphy, non-renormalization

$\mathcal{N} = 1$ dynamics, Seiberg duality

$\mathcal{N} = 2$ and Seiberg–Witten theory

SCFTs: the index, the bootstrap

6d (2,0), class $\mathcal{S}$ and AGT

SCFT / VOA, 3d mirror symmetry

Who should come

Everyone — all backgrounds welcome

Prerequisite: one full year of QFT

No susy background needed

Optional head start: first 50 pages of Wess & Bagger

Tu–Th 11:00–12:20, Math 6-125

The last topics are up for grabs — tell me what you would like to hear

PHY680 (Advanced Nonperturbative QFT):
Introduction to the dynamics of supersymmetric QFTs

Leonardo Rastelli

YITP seminar room (Math 6-125), Tu-Th 11:00am–12:20pm, Fall '26

In this class we will cover several aspects of supersymmetric quantum field theory, mostly in four spacetime dimensions, but with excursions to other dimensions as well. We will use supersymmetry as a crutch to learn both qualitative and quantitative lessons about quantum field theory dynamics. The subject has also deep connections to modern mathematics, but our emphasis will be on the physics.

Below is a list of the topics that I plan to cover. This selection is too long to fit in one semester, so the last few items are tentative and we'll make a choice based on how fast we'll go and on students' interests.

(a) Review of the basics of supersymmetric kinematics.

(b) Holomorphy and non-renormalization theorems.

(c) Dynamics of $\mathcal{N} = 1$ supersymmetric gauge theories for different gauge groups and matter content. Seiberg duality.

(d) $\mathcal{N} = 2$ field theories and Seiberg-Witten theory.

(e) Superconformal field theories. Representation theory and the superconformal index. The (super)conformal bootstrap.

(f) The $(2, 0)$ 6d theory and its compactifications to four dimensions. Theories of class $\mathcal{S}$ and the AGT correspondence.

(g) The SCFT/VOA correspondence.

(h) Three-dimensional mirror symmetry for $\mathcal{N} = 4$ theories.

Prerequisites. Everyone is welcome, but it's unlikely you will get much out of this class unless you have already taken at least a full year course in QFT, or have mastered that material by yourself (at the level say of Peskin-Schroeder or Srednicki). I will assume that you are comfortable with writing Lagrangians with scalars, fermions and gauge fields and the basic ideas about renormalization (e.g. that you can compute a simple one-loop Feynman integral and know what β functions and anomalous dimensions are). The basic kinematics of supersymmetry will be reviewed in class, but I will have to be quick because I want to get to dynamical aspects as soon as possible. So some previous exposure to the basics of 4d susy (e.g. how to write susy Lagrangians in $\mathcal{N} = 1$ superspace) would be helpful, but if you are a novice don't panic – for our purposes this will be mostly a matter of learning a few notational tricks. If you want to get a head start, a quick self-study of the first 50 pages of the book by Wess and Bagger (without necessarily going through all the detailed calculations) would be more than enough.