MIT School of Science - Physics Graduate Program

Year 1, Fall Semester: Classical Mechanics, Electromagnetism, and Mathematical Methods

Detailed Weekly Learning Schedule (40 hours per week)

Week 1: Introduction to Graduate Physics and Lagrangian Mechanics

Monday: Program Orientation and Classical Mechanics Foundations

Morning (4 hours):

- Graduate physics program introduction and curriculum overview
- Research opportunities in MIT physics departments
- Laboratory safety and research ethics orientation
- Classical mechanics review: Newton's laws and applications

Afternoon (4 hours):

- Introduction to Lagrangian formalism
- Generalized coordinates and constraints
- Calculus of variations basics
- Problem-solving workshop: Lagrangian derivation

Tuesday: Mathematical Methods - Complex Analysis Introduction

Morning (4 hours):

- Complex numbers and complex plane
- Complex functions and continuity
- Analyticity and Cauchy-Riemann equations
- Elementary functions in complex domain

Afternoon (4 hours):

- Complex integration and Cauchy's theorem

- Residue calculus introduction
- Applications to physics problems
- Problem-solving workshop: Complex analysis techniques

Wednesday: Electromagnetic Theory - Vector Calculus Review

Morning (4 hours):

- Vector algebra and vector calculus review
- Gradient, divergence, and curl operations
- Vector identities and theorems
- Coordinate systems (Cartesian, cylindrical, spherical)

Afternoon (4 hours):

- Laboratory: Vector field visualization
- Electrostatics review: Coulomb's law and Gauss's law
- Electric potential and fields
- Boundary value problems introduction

Thursday: Computational Physics - Programming Foundations

Morning (4 hours):

- Python programming for physics applications
- NumPy and SciPy libraries introduction
- Data structures and algorithms for physics
- Version control with Git

Afternoon (4 hours):

- Programming lab: Classical mechanics simulations
- Numerical integration methods
- Plotting and data visualization with Matplotlib
- Debugging and optimization techniques

Friday: Research Methods and Weekly Assessment

Morning (4 hours):

- Scientific method in physics research
- Literature review techniques
- Research ethics and integrity
- Collaboration and communication skills

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
  - Lagrangian mechanics (30%)
  - Complex analysis basics (25%)
  - Vector calculus applications (25%)
  - Programming fundamentals (20%)
- Exam review and discussion
- Week 2 preparation

Week 1 Assessment:

- Lagrangian derivation problems (15%)
- Complex analysis problem set (15%)
- Vector calculus exercises (15%)
- Programming assignment: simple simulation (15%)
- Research ethics quiz (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Classical Mechanics" (Taylor, Creative Commons)
- "Mathematical Methods for Physicists" (Arfken & Weber, Open Access)
- "Introduction to Electrodynamics" (Griffiths, Open Educational Resources)
- "Computational Physics with Python" (Newman, Open Access)
- "Physics Research Methods" (MIT OpenCourseWare)

Week 2: Principle of Least Action and Electromagnetic Fields

Monday: Lagrangian Mechanics - Principle of Least Action

Morning (4 hours):

- Hamilton's principle and action integral
- Euler-Lagrange equations derivation
- Symmetries and conservation laws
- Noether's theorem introduction

Afternoon (4 hours):

- Applications to oscillator systems
- Central force problems
- Coupled oscillator systems
- Problem-solving workshop: Action principle applications

Tuesday: Mathematical Methods - Fourier Analysis

Morning (4 hours):

- Fourier series and periodic functions
- Fourier transforms and applications
- Convolution theorem
- Parseval's theorem

Afternoon (4 hours):

- Applications to physics: heat equation, wave equation
- Fast Fourier Transform (FFT) algorithms
- Signal processing in physics
- Problem-solving workshop: Fourier analysis

Wednesday: Electromagnetic Theory - Electrostatics

Morning (4 hours):

- Electric fields and potential theory
- Multipole expansion
- Method of images
- Green's reciprocation theorem

Afternoon (4 hours):

- Laboratory: Electrostatic field mapping
- Boundary value problems
- Laplace and Poisson equations
- Numerical solutions to electrostatic problems

Thursday: Computational Physics - Numerical Methods

Morning (4 hours):

- Root finding algorithms
- Numerical differentiation and integration
- Ordinary differential equation solvers
- Runge-Kutta methods

Afternoon (4 hours):

- Programming lab: ODE solutions for physics
- Hamiltonian system simulations
- Phase space analysis
- Error analysis and stability

Friday: Scientific Communication and Weekly Assessment

Morning (4 hours):

- Technical writing for physics
- Figure preparation and data presentation
- Peer review process
- Citation and reference management

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
  - Principle of least action (30%)
  - Fourier analysis applications (25%)
  - Electrostatics problems (25%)
  - Numerical methods implementation (20%)
- Group discussion on physics applications
- Week 3 preparation

Week 2 Assessment:

- Action principle derivations (15%)
- Fourier analysis problem set (15%)
- Electrostatics boundary value problems (15%)
- Numerical ODE solver implementation (15%)
- Technical writing exercise (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Analytical Mechanics" (Hand & Finch, Open Access)
- "Mathematical Methods in Physics" (Mathews & Walker, OER)
- "Classical Electrodynamics" (Jackson, MIT OCW notes)
- "Numerical Recipes" (Press et al., Open Educational Resources)
- "Scientific Writing Guide" (MIT Writing Center)

Week 3: Hamiltonian Mechanics and Magnetostatics

Monday: Hamiltonian Mechanics Introduction

Morning (4 hours):

- Legendre transformation
- Hamilton's equations of motion

- Phase space and canonical coordinates
- Poisson brackets

Afternoon (4 hours):

- Canonical transformations
- Hamilton-Jacobi theory introduction
- Action-angle variables
- Problem-solving workshop: Hamiltonian systems

Tuesday: Mathematical Methods - Special Functions

Morning (4 hours):

- Gamma and beta functions
- Bessel functions and applications
- Legendre polynomials
- Spherical harmonics

Afternoon (4 hours):

- Sturm-Liouville theory
- Orthogonal function expansions
- Applications to boundary value problems
- Problem-solving workshop: Special functions

Wednesday: Electromagnetic Theory - Magnetostatics

Morning (4 hours):

- Magnetic fields and Biot-Savart law
- Ampère's law and applications
- Magnetic dipoles and multipoles
- Vector potential formulation

Afternoon (4 hours):

- Laboratory: Magnetic field measurements
- Boundary conditions for magnetic fields
- Magnetic materials introduction
- Inductance and magnetic energy

Thursday: Computational Physics - Monte Carlo Methods

Morning (4 hours):

- Random number generation

- Monte Carlo integration
- Markov Chain Monte Carlo
- Statistical error analysis

Afternoon (4 hours):

- Programming lab: Monte Carlo simulations
- Statistical mechanics applications
- Ising model simulation
- Convergence and efficiency analysis

Friday: Literature Review Skills and Weekly Assessment

Morning (4 hours):

- Database searching techniques
- Critical reading of physics papers
- Note-taking and organization systems
- Presentation preparation skills

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Hamiltonian mechanics (30%)
    - Special functions applications (25%)
    - Magnetostatics (25%)
    - Monte Carlo methods (20%)
- Literature review exercise
- Week 4 preparation

Week 3 Assessment:

- Hamiltonian mechanics problems (15%)
- Special functions problem set (15%)
- Magnetostatics calculations (15%)
- Monte Carlo simulation project (15%)
- Literature review report (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Classical Mechanics" (Goldstein, Open Access chapters)
- "Special Functions" (Andrews et al., Open Educational Resources)
- "Introduction to Electrodynamics" (Griffiths, OER version)
- "Monte Carlo Methods" (Landau & Binder, Open Access)
- "Physics Literature Guide" (APS Education Resources)

Week 4: Small Oscillations and Maxwell's Equations

Monday: Small Oscillations and Normal Modes

Morning (4 hours):

- Linearization about equilibrium
- Normal mode analysis
- Coupled oscillator systems
- Matrix methods for oscillations

Afternoon (4 hours):

- Continuous systems and wave equations
- String vibrations and membrane modes
- Dispersion relations
- Problem-solving workshop: Normal modes

Tuesday: Mathematical Methods - Green's Functions

Morning (4 hours):

- Green's function concept
- Construction methods
- Applications to differential equations
- Boundary value problems

Afternoon (4 hours):

- Green's functions in electrostatics
- Time-dependent Green's functions
- Integral equation formulations
- Problem-solving workshop: Green's functions

Wednesday: Electromagnetic Theory - Maxwell's Equations

Morning (4 hours):

- Faraday's law and electromagnetic induction
- Displacement current and Ampère-Maxwell law
- Maxwell's equations in vacuum
- Electromagnetic wave equation

Afternoon (4 hours):

- Laboratory: Electromagnetic induction experiments
- Wave propagation in free space
- Energy and momentum in electromagnetic fields
- Poynting vector and stress tensor

Thursday: Computational Physics - Partial Differential Equations

Morning (4 hours):

- Finite difference methods
- Boundary conditions implementation
- Stability and convergence analysis
- Grid generation techniques

Afternoon (4 hours):

- Programming lab: PDE solvers
- Heat equation and wave equation solutions
- Electromagnetic field simulations
- Visualization of field solutions

Friday: Research Proposal Writing and Weekly Assessment

Morning (4 hours):

- Research proposal structure
- Hypothesis formulation
- Methodology description
- Timeline and resource planning

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Small oscillations theory (30%)
    - Green's functions (25%)
    - Maxwell's equations (25%)
    - PDE numerical methods (20%)
- Research proposal workshop
- Week 5 preparation

Week 4 Assessment:

- Normal mode analysis problems (15%)
- Green's function applications (15%)
- Maxwell equation derivations (15%)
- PDE solver implementation (15%)
- Mini research proposal (10%)

- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Vibrations and Waves" (French, Open Access)
- "Green's Functions" (Stakgold, Open Educational Resources)
- "Classical Electrodynamics" (Jackson, MIT OCW)
- "Computational Physics" (Giordano & Nakanishi, OER)
- "Research Proposal Guide" (NSF Education Resources)

Week 5: Rigid Body Motion and Electromagnetic Waves

Monday: Rigid Body Dynamics

Morning (4 hours):

- Rotation matrices and Euler angles
- Angular momentum and inertia tensor
- Euler's equations for rigid body motion
- Gyroscopic effects

Afternoon (4 hours):

- Spinning top and precession
- Stability of rotation
- Rolling and sliding motion
- Problem-solving workshop: Rigid body systems

Tuesday: Mathematical Methods - Tensor Analysis

Morning (4 hours):

- Tensor definition and notation
- Tensor operations and transformations
- Metric tensor and differential geometry
- Applications in physics

Afternoon (4 hours):

- Stress and strain tensors
- Electromagnetic field tensor
- General relativity introduction
- Problem-solving workshop: Tensor applications

Wednesday: Electromagnetic Theory - Wave Propagation

Morning (4 hours):

- Plane wave solutions
- Polarization of electromagnetic waves
- Reflection and refraction at interfaces
- Fresnel equations

Afternoon (4 hours):

- Laboratory: Wave propagation experiments
- Waveguides and transmission lines
- Dispersion and group velocity
- Electromagnetic wave applications

Thursday: Computational Physics - Fourier Methods

Morning (4 hours):

- Discrete Fourier transform
- Fast Fourier Transform algorithms
- Spectral methods for PDEs
- Filtering and signal processing

Afternoon (4 hours):

- Programming lab: Spectral analysis
- Wave packet propagation simulations
- Fourier optics calculations
- Digital signal processing applications

Friday: Collaboration and Teamwork and Weekly Assessment

Morning (4 hours):

- Team dynamics in research
- Project management for physics
- Conflict resolution in scientific teams
- International collaboration practices

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Rigid body dynamics (30%)
    - Tensor analysis (25%)
    - Electromagnetic waves (25%)

    - Fourier methods (20%)
- Team building exercises
- Week 6 preparation

Week 5 Assessment:

- Rigid body motion problems (15%)
- Tensor analysis exercises (15%)
- Wave propagation calculations (15%)
- Spectral method implementation (15%)
- Team collaboration project (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Classical Mechanics" (Taylor, Open Access chapters)
- "Tensor Analysis" (Bowen & Wang, Open Educational Resources)
- "Electromagnetic Waves" (Staelin et al., MIT OCW)
- "Spectral Methods" (Trefethen, Open Access)
- "Scientific Collaboration Guide" (CERN Education)

Week 6: Continuous Systems and Advanced Electromagnetics

Monday: Continuous Media and Field Theory

Morning (4 hours):

- Field equations for continuous media
- Stress and strain in elastic media
- Fluid dynamics introduction
- Conservation laws in field theory

Afternoon (4 hours):

- Elastic wave propagation
- Acoustic waves and sound
- Nonlinear effects in continuous media
- Problem-solving workshop: Continuous systems

Tuesday: Mathematical Methods - Calculus of Variations

Morning (4 hours):

- Variational principles in physics
- Functional derivatives
- Constraints and Lagrange multipliers
- Noether's theorem applications

Afternoon (4 hours):

- Field theory and Lagrangian density
- Symmetries in field equations
- Variational methods in mechanics
- Problem-solving workshop: Variational calculus

Wednesday: Electromagnetic Theory - Materials and Optics

Morning (4 hours):

- Electromagnetic fields in matter
- Dielectric and magnetic materials
- Constitutive relations
- Boundary conditions in materials

Afternoon (4 hours):

- Laboratory: Optical properties of materials
- Dispersion and absorption
- Metamaterials and plasmonics introduction
- Optical instruments and systems

Thursday: Computational Physics - Finite Element Methods

Morning (4 hours):

- Weak formulation of PDEs
- Basis functions and interpolation
- Matrix assembly and solution
- Error estimation and refinement

Afternoon (4 hours):

- Programming lab: FEM implementation
- Structural mechanics problems
- Electromagnetic field calculations
- Mesh generation and optimization

Friday: Ethics in Physics Research and Weekly Assessment

Morning (4 hours):

- Research integrity and misconduct
- Data management and sharing
- Authorship and credit attribution
- Social responsibility of physicists

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Continuous media theory (30%)
    - Calculus of variations (25%)
    - Electromagnetic materials (25%)
    - Finite element methods (20%)
- Ethics case study discussions
- Week 7 preparation

Week 6 Assessment:

- Continuous systems analysis (15%)
- Variational calculus problems (15%)
- Materials electromagnetics (15%)
- FEM implementation project (15%)
- Ethics case study report (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Continuum Mechanics" (Lai et al., Open Access)
- "Calculus of Variations" (Gelfand & Fomin, Open Educational Resources)
- "Electromagnetic Fields in Matter" (Griffiths, OER)
- "Finite Element Methods" (Johnson, Open Access)
- "Physics Research Ethics" (APS Ethics Guidelines)

Week 7: Nonlinear Dynamics and Advanced Topics

Monday: Nonlinear Dynamics and Chaos

Morning (4 hours):

- Nonlinear oscillators and phase portraits
- Stability analysis and bifurcations
- Strange attractors and chaos
- Lyapunov exponents

Afternoon (4 hours):

- Driven nonlinear systems
- Period doubling and routes to chaos
- Control of chaotic systems
- Problem-solving workshop: Nonlinear dynamics

Tuesday: Mathematical Methods - Group Theory

Morning (4 hours):

- Group definition and examples
- Subgroups and cosets
- Group representations
- Applications to symmetry in physics

Afternoon (4 hours):

- Continuous groups and Lie groups
- Crystal symmetries
- Particle physics applications
- Problem-solving workshop: Group theory

Wednesday: Advanced Electromagnetic Topics

Morning (4 hours):

- Relativistic electromagnetism
- Four-vector formulation
- Electromagnetic field invariants
- Radiation from accelerated charges

Afternoon (4 hours):

- Laboratory: Radiation measurements
- Antenna theory and applications
- Electromagnetic scattering
- Advanced electromagnetic phenomena

Thursday: Computational Physics - Advanced Simulations

Morning (4 hours):

- Molecular dynamics simulations
- N-body problem algorithms
- Parallel computing concepts
- High-performance computing resources

Afternoon (4 hours):

- Programming lab: Advanced simulations
- Multi-physics modeling
- Visualization of complex systems
- Performance optimization techniques

Friday: Scientific Presentation Skills and Weekly Assessment

Morning (4 hours):

- Effective presentation design
- Visual aids and figure preparation
- Oral communication techniques
- Conference presentation guidelines

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
  - Nonlinear dynamics (30%)
  - Group theory applications (25%)
  - Advanced electromagnetics (25%)
  - Advanced computational methods (20%)
- Practice presentations
- Week 8 preparation

Week 7 Assessment:

- Nonlinear dynamics analysis (15%)
- Group theory applications (15%)
- Advanced electromagnetics problems (15%)
- Advanced simulation project (15%)
- Practice presentation evaluation (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Nonlinear Dynamics and Chaos" (Strogatz, Open Access)
- "Group Theory in Physics" (Cornwell, Open Educational Resources)
- "Classical Electrodynamics" (Jackson, advanced chapters)
- "Computational Physics" (Thijssen, Open Access)
- "Scientific Presentation Guide" (Nature Education)

Week 8: Special Relativity and Field Theory

Monday: Special Relativity Foundations

Morning (4 hours):

- Postulates of special relativity
- Lorentz transformations
- Time dilation and length contraction
- Relativistic velocity addition

Afternoon (4 hours):

- Spacetime diagrams and worldlines
- Simultaneity and causality
- Twin paradox and clock synchronization
- Problem-solving workshop: Special relativity

Tuesday: Mathematical Methods - Advanced Differential Equations

Morning (4 hours):

- Partial differential equations classification
- Method of characteristics
- Separation of variables advanced techniques
- Transform methods

Afternoon (4 hours):

- Integral equation methods
- Asymptotic analysis
- Perturbation theory
- Problem-solving workshop: Advanced ODEs/PDEs

Wednesday: Relativistic Electromagnetics

Morning (4 hours):

- Four-vector formulation of electromagnetism
- Electromagnetic field tensor
- Lorentz force in relativistic form
- Gauge invariance and transformations

Afternoon (4 hours):

- Laboratory: High-energy particle detection
- Synchrotron radiation
- Relativistic particle dynamics
- Applications in accelerator physics

Thursday: Computational Physics - Numerical Relativity

Morning (4 hours):

- Spacetime discretization methods
- Einstein field equations numerically
- Gravitational wave simulations
- Relativistic hydrodynamics

Afternoon (4 hours):

- Programming lab: Relativistic simulations
- Particle trajectory calculations
- Electromagnetic field evolution
- Visualization of relativistic effects

Friday: Grant Writing and Funding and Weekly Assessment

Morning (4 hours):

- Grant proposal structure
- Budget preparation
- Review process understanding
- Funding agency landscape

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Special relativity (30%)
    - Advanced differential equations (25%)
    - Relativistic electromagnetics (25%)
    - Numerical relativity (20%)
- Grant writing workshop
- Week 9 preparation

Week 8 Assessment:

- Special relativity problems (15%)
- PDE solutions (15%)
- Relativistic electromagnetics (15%)
- Numerical relativity project (15%)
- Mini grant proposal (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Special Relativity" (Einstein, Open Access translation)
- "Differential Equations" (Blanchard et al., OER)
- "Relativistic Electromagnetism" (Landau & Lifshitz, Open Access)

- "Numerical Relativity" (Baumgarte & Shapiro, OER chapters)
- "Grant Writing Guide" (NSF Resources)

Week 9: Statistical Mechanics Introduction and Advanced Mathematics

Monday: Statistical Mechanics Foundations

Morning (4 hours):

- Microscopic and macroscopic descriptions
- Phase space and ensembles
- Microcanonical ensemble
- Entropy and temperature

Afternoon (4 hours):

- Canonical ensemble derivation
- Partition function and thermodynamic relations
- Heat capacity and fluctuations
- Problem-solving workshop: Statistical ensembles

Tuesday: Mathematical Methods - Complex Variable Applications

Morning (4 hours):

- Contour integration techniques
- Branch cuts and multi-valued functions
- Conformal mapping
- Applications to physics problems

Afternoon (4 hours):

- Dispersion relations
- Kramers-Kronig relations
- Analytic continuation
- Problem-solving workshop: Complex analysis applications

Wednesday: Thermodynamics and Phase Transitions

Morning (4 hours):

- Laws of thermodynamics review

- Thermodynamic potentials
- Maxwell relations
- Phase equilibrium conditions

Afternoon (4 hours):

- Laboratory: Phase transition measurements
- Critical phenomena introduction
- Order parameters and symmetry breaking
- Landau theory of phase transitions

Thursday: Computational Physics - Statistical Simulations

Morning (4 hours):

- Random sampling techniques
- Metropolis algorithm
- Simulated annealing
- Statistical error analysis

Afternoon (4 hours):

- Programming lab: Statistical mechanics simulations
- Ising model implementation
- Monte Carlo thermodynamics
- Data analysis and error estimation

Friday: Professional Development and Weekly Assessment

Morning (4 hours):

- Career paths in physics
- Industry vs. academia considerations
- Networking and professional societies
- Continuing education planning

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
  - Statistical mechanics foundations (30%)
  - Complex analysis applications (25%)
  - Thermodynamics and phase transitions (25%)
  - Statistical simulations (20%)
- Career planning workshop
- Week 10 preparation

Week 9 Assessment:

- Statistical mechanics problems (15%)
- Complex analysis applications (15%)
- Phase transition analysis (15%)
- Statistical simulation project (15%)
- Professional development plan (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Statistical Mechanics" (Pathria, Open Access chapters)
- "Complex Variables" (Churchill & Brown, OER)
- "Thermodynamics and Statistical Mechanics" (Kittel, Open Educational Resources)
- "Statistical Physics Simulations" (Gould & Tobochnik, Open Access)
- "Physics Career Guide" (APS Career Resources)

Week 10: Quantum Mechanics Preparation and Advanced Simulations

Monday: Classical to Quantum Transition

Morning (4 hours):

- Limitations of classical mechanics
- Black body radiation and Planck's hypothesis
- Photoelectric effect and Compton scattering
- de Broglie waves and matter waves

Afternoon (4 hours):

- Wave-particle duality
- Uncertainty principle derivation
- Classical-quantum correspondence
- Problem-solving workshop: Quantum foundations

Tuesday: Mathematical Methods - Linear Algebra in Physics

Morning (4 hours):

- Vector spaces and inner products
- Linear operators and matrices
- Eigenvalue problems in physics
- Diagonalization and similarity transformations

Afternoon (4 hours):

- Hermitian and unitary operators
- Spectral decomposition
- Matrix functions and exponentials
- Problem-solving workshop: Linear algebra applications

Wednesday: Wave Mechanics Introduction

Morning (4 hours):

- Schrödinger equation derivation
- Wave function interpretation
- Probability current and continuity equation
- Time evolution and stationary states

Afternoon (4 hours):

- Laboratory: Wave optics experiments
- Particle in a box solutions
- Infinite square well analysis
- Quantum tunneling introduction

Thursday: Computational Physics - Quantum Simulations

Morning (4 hours):

- Numerical solution of Schrödinger equation
- Finite difference methods for quantum problems
- Matrix diagonalization algorithms
- Time evolution algorithms

Afternoon (4 hours):

- Programming lab: Quantum mechanics simulations
- Wave packet evolution
- Potential scattering calculations
- Visualization of quantum phenomena

Friday: Research Collaboration and Weekly Assessment

Morning (4 hours):

- Collaborative research practices
- International physics collaborations
- Data sharing and open science
- Remote collaboration tools

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Classical-quantum transition (30%)
    - Linear algebra in physics (25%)
    - Wave mechanics basics (25%)
    - Quantum simulations (20%)
- Collaboration project planning
- Week 11 preparation

Week 10 Assessment:

- Quantum foundations problems (15%)
- Linear algebra applications (15%)
- Wave mechanics calculations (15%)
- Quantum simulation project (15%)
- Collaboration project proposal (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Introduction to Quantum Mechanics" (Griffiths, Open Access chapters)
- "Linear Algebra for Physics" (Goldbart & Steffen, OER)
- "Quantum Mechanics Simulations" (Johnston, Open Educational Resources)
- "Scientific Collaboration Guide" (CERN Education Resources)

Week 11: Advanced Classical Topics and Research Methods

Monday: Celestial Mechanics and Gravitational Systems

Morning (4 hours):

- Kepler's laws and orbital mechanics
- Two-body problem solution
- Perturbation theory in celestial mechanics
- Three-body problem introduction

Afternoon (4 hours):

- Lagrange points and stability
- Tidal forces and effects
- Gravitational N-body simulations
- Problem-solving workshop: Gravitational systems

Tuesday: Mathematical Methods - Asymptotic Analysis

Morning (4 hours):

- Asymptotic expansions and series
- Method of steepest descent
- WKB approximation
- Stationary phase method

Afternoon (4 hours):

- Applications to wave problems
- Semiclassical quantum mechanics
- Perturbation theory mathematics
- Problem-solving workshop: Asymptotic methods

Wednesday: Plasma Physics Introduction

Morning (4 hours):

- Plasma definition and parameters
- Debye shielding and plasma frequency
- Plasma oscillations and waves
- Magnetohydrodynamics basics

Afternoon (4 hours):

- Laboratory: Plasma generation and diagnosis
- Fusion plasma physics
- Space plasma phenomena
- Computational plasma modeling

Thursday: Computational Physics - Advanced Algorithms

Morning (4 hours):

- Optimization algorithms
- Machine learning for physics
- Genetic algorithms and evolution
- Parallel processing concepts

Afternoon (4 hours):

- Programming lab: Advanced algorithms
- Neural networks for physics problems
- Genetic algorithm optimization
- Parallel computing implementation

Friday: Research Project Development and Weekly Assessment

Morning (4 hours):

- Research project planning
- Experimental design principles
- Data collection strategies
- Project timeline development

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Celestial mechanics (30%)
    - Asymptotic analysis (25%)
    - Plasma physics basics (25%)
    - Advanced algorithms (20%)
- Research project presentations
- Week 12 preparation

Week 11 Assessment:

- Celestial mechanics problems (15%)
- Asymptotic analysis applications (15%)
- Plasma physics calculations (15%)
- Advanced algorithm implementation (15%)
- Research project proposal (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Celestial Mechanics" (Pollard, Open Access)
- "Asymptotic Analysis" (Hinch, Open Educational Resources)
- "Plasma Physics" (Chen, OER chapters)
- "Machine Learning for Physics" (Mehta et al., Open Access)
- "Research Methods in Physics" (MIT OpenCourseWare)

Week 12: Condensed Matter Basics and Modern Physics

Monday: Solid State Physics Introduction

Morning (4 hours):

- Crystal structure and lattices
- X-ray diffraction and structure determination
- Reciprocal lattice and Brillouin zones

- Electronic band theory basics

Afternoon (4 hours):

- Free electron model
- Fermi surface and electronic properties
- Phonons and lattice dynamics
- Problem-solving workshop: Solid state systems

Tuesday: Mathematical Methods - Perturbation Theory

Morning (4 hours):

- Regular and singular perturbation theory
- Multiple scale analysis
- Boundary layer theory
- Applications to oscillator problems

Afternoon (4 hours):

- Quantum mechanical perturbation theory
- Time-dependent perturbations
- Adiabatic approximation
- Problem-solving workshop: Perturbation methods

Wednesday: Atomic and Molecular Physics

Morning (4 hours):

- Hydrogen atom solution review
- Multi-electron atoms
- Atomic spectra and selection rules
- Molecular bonding introduction

Afternoon (4 hours):

- Laboratory: Atomic spectroscopy
- Laser physics basics
- Atomic structure calculations
- Molecular orbital theory

Thursday: Computational Physics - Materials Modeling

Morning (4 hours):

- Density functional theory introduction
- Molecular dynamics for solids

- Band structure calculations
- Materials property prediction

Afternoon (4 hours):

- Programming lab: Materials simulations
- Crystal structure analysis
- Electronic structure calculations
- Visualization of materials properties

Friday: Technology Transfer and Weekly Assessment

Morning (4 hours):

- Physics in technology development
- Patent process and intellectual property
- Industry-academia partnerships
- Commercialization of research

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Solid state physics (30%)
    - Perturbation theory (25%)
    - Atomic and molecular physics (25%)
    - Materials modeling (20%)
- Technology transfer workshop
- Week 13 preparation

Week 12 Assessment:

- Solid state physics problems (15%)
- Perturbation theory applications (15%)
- Atomic physics calculations (15%)
- Materials modeling project (15%)
- Technology assessment report (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Solid State Physics" (Ashcroft & Mermin, Open Access chapters)
- "Perturbation Methods" (Nayfeh, Open Educational Resources)
- "Atomic Physics" (Foot, OER)
- "Materials Modeling" (Kaplan, Open Access)
- "Physics Technology Transfer" (APS Industry Resources)

Week 13: Nuclear Physics and High Energy Concepts

Monday: Nuclear Physics Foundations

Morning (4 hours):

- Nuclear structure and properties
- Radioactive decay and half-lives
- Nuclear reactions and cross-sections
- Fission and fusion processes

Afternoon (4 hours):

- Nuclear models and shell structure
- Gamma ray spectroscopy
- Nuclear astrophysics connections
- Problem-solving workshop: Nuclear physics

Tuesday: Mathematical Methods - Integral Equations

Morning (4 hours):

- Fredholm and Volterra equations
- Kernel functions and eigenfunction expansions
- Scattering theory applications
- Numerical solution methods

Afternoon (4 hours):

- Born approximation
- Optical theorem
- Multiple scattering theory
- Problem-solving workshop: Integral equations

Wednesday: Particle Physics Introduction

Morning (4 hours):

- Elementary particle classification
- Fundamental forces and interactions
- Conservation laws in particle physics
- Feynman diagrams introduction

Afternoon (4 hours):

- Laboratory: Particle detection methods

- Accelerator physics basics
- Cosmic ray physics
- Standard model overview

Thursday: Computational Physics - High Energy Simulations

Morning (4 hours):

- Event generation algorithms
- Particle tracking simulations
- Detector response modeling
- Data analysis techniques

Afternoon (4 hours):

- Programming lab: Particle physics simulations
- Monte Carlo event generation
- Detector geometry modeling
- Statistical data analysis

Friday: Science Policy and Weekly Assessment

Morning (4 hours):

- Science policy and government
- Funding agency structures
- International scientific cooperation
- Public understanding of science

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
    - Nuclear physics (30%)
    - Integral equations (25%)
    - Particle physics basics (25%)
    - High energy simulations (20%)
- Science policy discussion
- Week 14 preparation

Week 13 Assessment:

- Nuclear physics problems (15%)
- Integral equation solutions (15%)
- Particle physics calculations (15%)
- High energy simulation project (15%)
- Science policy analysis (10%)
- Weekly comprehensive exam (30%) - Friday

Reference Materials:

- "Nuclear Physics" (Evans, Open Access)
- "Integral Equations" (Tricomi, Open Educational Resources)
- "Particle Physics" (Martin & Shaw, OER chapters)
- "Particle Physics Simulations" (CERN Education)
- "Science Policy Resources" (AAAS Policy)

Week 14: Advanced Topics and Project Integration

Monday: Biophysics and Interdisciplinary Physics

Morning (4 hours):

- Physics principles in biological systems
- Biomechanics and elasticity
- Membrane physics and ion channels
- Molecular motors and transport

Afternoon (4 hours):

- Medical physics applications
- Imaging techniques and physics
- Radiation therapy physics
- Problem-solving workshop: Biophysics

Tuesday: Mathematical Methods - Stochastic Processes

Morning (4 hours):

- Random walks and diffusion
- Markov processes
- Langevin and Fokker-Planck equations
- Applications to physical systems

Afternoon (4 hours):

- Brownian motion and fluctuations
- Noise in physical systems
- Stochastic resonance
- Problem-solving workshop: Stochastic methods

Wednesday: Advanced Laboratory Techniques

Morning (4 hours):

- Vacuum technology and ultra-high vacuum
- Cryogenic techniques and low temperatures
- High magnetic field systems
- Precision measurement techniques

Afternoon (4 hours):

- Laboratory: Advanced instrumentation
- Lock-in amplifiers and signal recovery
- Computer-controlled experiments
- Error analysis and uncertainty quantification

Thursday: Computational Physics - Final Projects

Morning (4 hours):

- Project planning and design
- Code organization and documentation
- Performance optimization
- Testing and validation

Afternoon (4 hours):

- Final project development
- Individual consultation
- Code review and debugging
- Presentation preparation

Friday: Professional Presentation and Weekly Assessment

Morning (4 hours):

- Final project presentations
- Peer review and feedback
- Portfolio development
- Professional networking

Afternoon (4 hours):

- Weekly comprehensive exam (2 hours)
  - Biophysics applications (25%)
  - Stochastic processes (25%)
  - Advanced laboratory techniques (25%)
  - Computational project evaluation (25%)
- Presentation skills evaluation

- Week 15 preparation

Week 14 Assessment:

- Biophysics problem analysis (15%)
- Stochastic process applications (15%)
- Laboratory technique report (15%)
- Final computational project (20%)
- Professional presentation (15%)
- Weekly comprehensive exam (20%) - Friday

Reference Materials:

- "Biophysics" (Nelson, Open Access chapters)
- "Stochastic Processes in Physics" (Van Kampen, OER)
- "Advanced Laboratory Techniques" (MIT Physics Labs)
- "Computational Physics Projects" (Newman, Open Access)
- "Professional Presentation Guide" (Nature Education)

Week 15: Comprehensive Review and Final Assessment

Monday: Classical Mechanics and Electromagnetism Review

Morning (4 hours):

- Lagrangian and Hamiltonian mechanics review
- Canonical transformations and conservation laws
- Maxwell's equations and electromagnetic waves
- Relativistic mechanics and electromagnetism

Afternoon (4 hours):

- Comprehensive problem-solving workshop
- Integration of classical concepts
- Applications to modern physics
- Group review sessions

Tuesday: Mathematical Methods Comprehensive Review

Morning (4 hours):

- Complex analysis and special functions
- Differential equations and Green's functions

- Vector calculus and tensor analysis
- Fourier analysis and transforms

Afternoon (4 hours):

- Mathematical physics integration
- Problem-solving strategies
- Computational implementation
- Cross-disciplinary applications

Wednesday: Statistical Mechanics and Thermodynamics Review

Morning (4 hours):

- Ensembles and partition functions
- Phase transitions and critical phenomena
- Quantum statistical mechanics introduction
- Thermodynamic relations and applications

Afternoon (4 hours):

- Statistical mechanics applications
- Simulation methods review
- Data analysis techniques
- Connection to experimental results

Thursday: Modern Physics and Advanced Topics Review

Morning (4 hours):

- Quantum mechanics foundations
- Atomic and nuclear physics
- Solid state and condensed matter
- Particle physics basics

Afternoon (4 hours):

- Interdisciplinary physics applications
- Current research frontiers
- Future directions in physics
- Career pathway discussions

Friday: Final Comprehensive Assessment and Semester Conclusion

Morning (4 hours):

- Portfolio presentation

- Comprehensive oral examination
- Research proposal defense
- Peer evaluation sessions

Afternoon (4 hours):

- Final comprehensive examination (3 hours)
  - Classical mechanics and electromagnetism (30%)
  - Mathematical methods integration (25%)
  - Statistical mechanics and thermodynamics (25%)
  - Modern physics and applications (20%)
- Semester reflection and feedback
- Next semester preparation

Week 15 Assessment:

- Comprehensive problem sets (20%)
- Portfolio evaluation (20%)
- Oral examination (15%)
- Research proposal quality (15%)
- Final comprehensive examination (30%) - Friday

Reference Materials:

- "Classical Physics Comprehensive Review" (MIT OCW)
- "Mathematical Methods in Physics" (Comprehensive OER)
- "Statistical Mechanics Review" (Pathria, summary chapters)
- "Modern Physics Survey" (Beiser, Open Access)
- "Graduate Physics Assessment Guide" (APS Education)

Semester Assessment Summary

Total Grade Breakdown:

- Weekly Comprehensive Exams (15 weeks × 2%): 30%
- Problem Sets and Homework: 25%
- Laboratory Reports and Projects: 20%
- Research and Professional Development: 15%
- Final Comprehensive Examination: 10%

Learning Outcomes Achievement: Students completing this semester will have:

1. Mastered advanced classical mechanics and electromagnetic theory
2. Developed strong mathematical physics problem-solving skills

3. Gained proficiency in computational physics methods
4. Established foundation for quantum mechanics and statistical physics
5. Developed research and professional skills for graduate study

Preparation for Year 1, Spring Semester: Students will be prepared to tackle quantum mechanics, advanced statistical mechanics, and specialized physics topics in the spring semester.