Centre for High Energy Physics
Faculty of Science
University of the Punjab, Lahore
Course Outline

Program	BSCP	**Course Code**	ACS 406	**Credit Hours**	3
Course Title	**Machine Learning**				

Course Introduction

This course covers both fundamental and advanced concepts and techniques in machine learning, with a specific focus on applications in computational physics. Students will learn about various machine learning algorithms, model evaluation methods, and the implementation of these techniques to solve physics-related problems. The course will include hands-on projects and case studies in physics.

Learning Outcomes

- Understand the scope and evolution of machine learning.
- Learn and apply different types of machine learning algorithms.
- Evaluate and select appropriate models for different problems.
- Implement machine learning techniques to solve computational physics problems.
- Explore advanced machine learning techniques and their applications in physics.

Course Content

Week 1	Introduction to Machine Learning • Definition and Scope of Machine Learning • History and Evolution of Machine Learning
Week 2	Types of Machine Learning • Supervised Learning • Unsupervised Learning • Reinforcement Learning
Week 3	Linear Regression and Advanced Regression Techniques • Introduction to Linear Models • Gradient Descent and Optimization • Overfitting and Regularization • Ridge and Lasso Regression • Bayesian Regression
Week 4	Classification Algorithms and Advanced Classification Techniques • Logistic Regression • k-Nearest Neighbors (k-NN) • Support Vector Machines (SVM) with Kernels • Multi-Class Classification
Week 5	Model Evaluation and Selection • Performance Metrics: Accuracy, Precision, Recall, F1-Score • Cross-Validation • Bias-Variance Tradeoff • ROC Curves and AUC

Week 6	Decision Trees and Ensemble Methods
	• Decision Trees
	    o Splitting Criteria
	    o Pruning
	• Ensemble Methods
	    o Bagging and Random Forests
	    o Boosting (AdaBoost, Gradient Boosting)

Week 7	Unsupervised Learning
	• Clustering
	    o k-Means Clustering
	    o Hierarchical Clustering
	    o DBSCAN
	• Dimensionality Reduction
	    o Principal Component Analysis (PCA)
	    o t-Distributed Stochastic Neighbor Embedding (t-SNE)

Week 8	Neural Networks and Deep Learning Basics
	• Introduction to Neural Networks
	    o Perceptron and Multilayer Perceptron
	    o Activation Functions
	    o Backpropagation
	• Basics of Deep Learning
	    o Introduction to Deep Neural Networks
	    o Regularization Techniques (Dropout, Batch Normalization)

Week 9	Convolutional Neural Networks (CNNs) • Convolution Operations • CNN Architectures and Applications

Week 10	Sequence Modeling and Recurrent Neural Networks (RNNs)
	• Introduction to Sequence Modeling
	• Recurrent Neural Networks (RNNs)
	    o Long Short-Term Memory (LSTM)
	    o Gated Recurrent Units (GRUs)
	• Applications in Time-Series Prediction and Sequence Generation

Week 11	Unsupervised Deep Learning
	• Autoencoders
	    o Denoising Autoencoders
	    o Variational Autoencoders (VAEs)
	• Generative Adversarial Networks (GANs)
	    o GAN Architecture and Training
	    o Applications of GANs

Week 12	Reinforcement Learning
	• Introduction to Reinforcement Learning
	    o Markov Decision Processes (MDPs)
	    o Q-Learning and Deep Q Networks (DQNs)
	• Advanced Reinforcement Learning Techniques
	    o Policy Gradients
	    o Actor-Critic Methods

Week 13	Advanced Applications in Physics I • Machine Learning in Particle Physics o Data Analysis and Pattern Recognition in High-Energy Physics

	• Machine Learning for Quantum Mechanics ○ Quantum Machine Learning Algorithms
Week 14	Advanced Applications in Physics II • Project Work: Applying Machine Learning Techniques to a Physics Problem
Week 15	Research and Development in Machine Learning • Current Trends and Research in Machine Learning • Reading and Presenting Research Papers • Ethical Considerations and Future Directions
Week 16	**Applications in Physics** • Project work: Applying machine learning techniques to a physics problem Comprehensive Review of Key Concepts and Techniques • Practice Problems • Final Project Presentations

Textbooks and Reading Material

1. **Pattern Recognition and Machine Learning** by Christopher M. Bishop
2. **Machine Learning: A Probabilistic Perspective** by Kevin P. Murphy
3. **An Introduction to Statistical Learning** by Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani
4. **Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow** by Aurélien Géron
5. **Deep Learning** by Ian Goodfellow, Yoshua Bengio, and Aaron Courville
6. **Reinforcement Learning: An Introduction** by Richard S. Sutton and Andrew G. Barto
7. **Bayesian Reasoning and Machine Learning** by David Barber
8. **Deep Reinforcement Learning Hands-On** by Maxim Lapan
9. **Neural Networks and Deep Learning: A Textbook** by Charu C. Aggarwal

Teaching Learning Strategies

The instructor is required to make use of Mathematica/Maple/Python to teach the concepts through visualization/antimutation and symbolic/numerical calculations. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. At least fifty percent of the question paper would involve new problems related to the concepts learned in the course. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	**Course Code**	CPHY 452	**Credit Hours**	3
Course Title	**Particle Physics**				

Course Introduction

The course introduces particle physics at undergraduate level.

Learning Outcomes

On the completion of the course, the students will:

1. Learn properties of fundamental particles from historical perspective.
2. Studying the probes in high energy physics.
3. Symmetries and their applications.

Course Content

Week 1	Historical Introduction to Particle Physics
	Elementary particles and fundamental forces
Week 2	Antiparticles
	Mesons
Week 3	Neutrinos
	Lepton and baryon numbers
Week 4	Strange particles and strange quantum number
	Eightfold way
Week 5	Quark model
	Natural system of units
Week 6	(Problem solving)
	Modern particle colliders and detector
Week 7	(Continuing)
	Nature of the experimental data in particle physics
Week 8	Decay rates
	Differential and total cross-sections
Week 9	Continuous and discrete symmetries
	Space-time symmetries in quantum mechanics and the laws of conservation
Week 10	Consequences of symmetries
	Translational and rotation symmetries

Week 11	Parity and its violation in weak interaction
	Internal symmetries
Week 12	Charge conjugation and C parity
	Isospin symmetry and its application
Week 13	CP violation
	(Problem solving)
Week 14	Quantum fields
	The standard model of particle physics
Week 15	Higgs mechanism.
	Incompleteness of the standard model
Week 16	Dark matter, matter-antimatter asymmetry
	Beyond the standard model (BSM) theories.

Textbooks and Reading Material

1. Introduction to elementary particles, D. Griffiths, *John Wiley & Sons* (1987).
2. Quarks and leptons, F. Halzen and A. D. Martin, *John Wiley & Sons* (1984).
3. Special Relativity: Applications to Particle Physics and Classical Theory of Fields, M. Saleem and M. Rafique, *Ellis Horwood*(1992).
4. A Modern Introduction to Particle Physics, Riazuddin and Fayyuddin, *World Scientific* (1992).
5. Quantum Mechanics, Thankapan, *John Wiley India* (1993).
6. Introduction to High Energy Physics, D. H. Perkins, *Addison Wesley* (2000).

Teaching Learning Strategies

The instructor is required to make use of Mathematica/Maple/Python to teach the concepts through visualization/antimutation and symbolic/numerical calculations. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	Course Code	CPHY 453	Credit Hours	3
Course Title	**Advanced Quantum Mechancs**				

Course Introduction

The course cover advance topic in quantum mechanics at undergraduate level.

Learning Outcomes

On the completion of the course, the students will:

1. Scattering theory in quantum mechaincs.
2. Partial waveanalysis.
3. Relativisitic quantum mechaincs
4. Relativisitc perturbation theory and applications.

Course Content

Week 1	Partial Wave analysis: Boundary conditions of scattering in quantum mechanics
	Relation between differential cross section and scattering amplitude
Week 2	Solution of free Schrodinger in equation in cartesian and spherical coordinates
	Relation between spherical and plane waves
Week 3	Scattering amplitude for scattering by spherically symmetric potential
	Partial phases
Week 4	Dependence of partial phases on energy and angular momentum.
	Optical theorem
Week 5	Simple applications of scattering theory
	Breit-Wigner resonance formula
Week 6	Scattering by complex potential and absorption process
	(Continued)
Week 7	Relativistic quantum mechanics
	Klein-Gordan equation KG and Dirac equations, conserve current, and their plane wave solutions. Effect of electromagnetic interaction. Scattering Theory: Scattering amplitude in non-relativistic and relativistic perturbation theory, Fermi golden rule, Feynman rules of quantum electrodynamics, scattering cross sections of electron-muon elastic scattering and electron-positron scattering.
Week 8	Equation of continuity of KG equation and problem of -ve probabilities density
	Plane wave solutions KG equation
Week 9	KG equation is covariant form

	Dirac equation
Week 10	Equation of continuity of Dirac equation
	Covariant form of Dirac equation
Week 11	Properties and representation of gamma matrices
	Plane wave solutions of Dirac equation
Week 12	Dirac spinors
	Scattering amplitude in non-relativistic perturbation theory
Week 13	Relativistic perturbation theory
	Fermi golden rule
Week 14	Covariant form of Maxwell equation
	Covariant polarization vectors
Week 15	Feynman rules and diagram of quantum electrodynamics
	(continued)
Week 16	Calculating scattering cross section of $e^+e^- \rightarrow \mu^+\mu^-$
	Fermion spin sum.

Textbooks and Reading Material

1. Introduction to elementary particles, D. Griffiths, *John Wiley & Sons* (1987).
2. Quarks and leptons, F. Halzen and A. D. Martin, *John Wiley & Sons* (1984).
3. Special Relativity: Applications to Particle Physics and Classical Theory of Fields, M. Saleem and M. Rafique, *Ellis Horwood*(1992).
4. A Modern Introduction to Particle Physics, Riazuddin and Fayyuddin, *World Scientific* (1992).
5. Quantum Mechanics, Thankapan, *John Wiley India* (1993).
6. Introduction to High Energy Physics, D. H. Perkins, *Addison Wesley* (2000).

Teaching Learning Strategies

The instructor is required to make use of Mathematica/Maple/Python to teach the concepts through visualization/antimutation and symbolic/numerical calculations. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	**Course Code**	CPHY 454	**Credit Hours**	3
Course Title	**Detector Physics**				

Course Introduction

This course deals with mainly the interaction of microscopic particles (radiation) with the material through which they pass. The detailed mechanisms/processes involved during such interaction are to be focused in this course. Devices called detectors which are used to measure the effects of interaction, will be detailed out along-with their applications. Learning of such course will develop necessary knowledge in the student minds so that they can excel in different fields such as High Energy Physics, Medical Physics, Material Physics, Space Physics etc.

Learning Outcomes

Following objectives are expected at the end of this course:

1. Learning of different of mechanism of energy loss of radiation in matter.
2. Learning of working principles and applications of particles detector.

Course Content

Week 1	Course Introduction involving its scope and applications, etc.
	Energy loss by radiation through ionization and excitations
Week 2	Bohr's Classical formula for energy loss
	Bethe-Bloch formula for energy loss
Week 3	Bremsstrahlung, Interactions of photons
	Ionization counter
Week 4	Proportional counters
	Geiger counter
Week 5	Scintillation counters, Photomultipliers and photodiodes
	Cherenkov counters
Week 6	Cloud chambers, Bubble chambers
	Multiwire proportional chambers
Week 7	Drift chambers
	Time-projection chambers
Week 8	Semiconductor track detectors
	Electromagnetic calorimeters
Week 9	Electron-photon cascades
	Homogeneous calorimeters

Week 10	Sampling calorimeters	
	Hadron calorimeters	
Week 11	Charged-particle identification	
	Time-of-flight counters	
Week 12	Identification by ionization losses	
	Neutron detection	
Week 13	Introduction to Detector Simulation Softwares; GEANT4(GEometryANd Tracking 4)	
	Installation Details of GEANT4 and Its Allied softwares	
Week 14	Simulation categories of GEANT4	
	Geometrical construction of detectors in GEANT4	
Week 15	Material definitions in the detector geometry in GEANT4	
	Defining Physics Processes and Particles in GEANT4	
Week 16	GAENT4 Action Classes	
	Execution of particle passage through a simple detector; An example	

Textbooks and Reading Material

1. Particle Detectors (2ndEdition), C. Grupen and B. Shwartz, *Cambridge Monographs on Particles Physics, Nuclear Physics and Cosmology* (2008).
2. Radiation Detection and Measurements (2nd edition), G. F. Knoll, *John Willey* (1989).
3. Introduction to High Energy Physics (3nd edition), D. Perkins, *Addison-Welsey*(1987).
4. Techniques for Nuclear and Particle Physics Experiments (2nd edition), W. R. Leo, *Springer-Verlag*(1994).
5. Instrumentation in High Energy Physics, Sauli, *World Scientific* (1993)
6. Review of Particle Properties, Phys. Rev. D 98, 030001 (2018).

Softwares:
GEANT4 and its Allied Softwares, Website: https://geant4.web.cern.ch/

Teaching Learning Strategies

1. The instructor will detail out the concepts particle interaction with matter, starting with basic examples
2. The instructor will use detector simulation softwares such as GEANT4 for trying out effective explanations of the concepts of particle interactions
3. Students will need to solve particle interaction exercise problems in the suggested textbooks
4. For better understanding of the concepts of particles and detectors, students should install and learn the sophisticated software of GEANT4

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details

1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	**Course Code**	CPHY 455	**Credit Hours**	3
Course Title	**Accelerator Physics**				

Course Introduction

This course deals with the electromagnetic devices which are used for accelerating different types of particles. There are different types of particle accelerators which will be discussed in detail. This course is of paramount significance in the field of High Energy Physics, radiation physics, etc.

Learning Outcomes

Following objectives are expected at the end of this course:

1. Learning of the physics of particle accelerator and related phenomena.
2. Learning the related electronics coupled with design of particle accelerators.

Course Content

Week 1	Course Introduction involving its scope and applications, etc.
	Historical Developments of accelerators
Week 2	Layouts and Components of Accelerators
	Accelerator Applications
Week 3	Hamiltonian for particle motion in accelerators
	Linear accelerators
Week 4	Circular accelerators.
	Betatron accelerator
Week 5	Effect of linear magnet imperfections
	Off-momentum Orbits
Week 6	Chromatic aberration
	Linear coupling
Week 7	Nonlinear resonances
	Collective instabilities
Week 8	Landau Damping
	Synchrotron Motion
Week 9	Longitudinal equation of motion
	Adiabatic synchrotron motion
Week 10	RF Phase and voltage Modulations

	Non-adiabatic and nonlinear synchrotron motion
Week 11	Beam manipulation in synchrotron phase space
	Fundamentals of RF systems
Week 12	Longitudinal collective instabilities
	Famous Accelerators of the world
Week 13	A discussion on cosmological accelerator
	Large Electron Positron Collider (LEPC)
Week 14	Large Hadron Collider (LHC)
	Beijing Electron Positron Colliders
Week 15	Future Colliders
	International Linear Collider (ILC)
Week 16	Circular Electron Positron Collider (CEPC)
	Super Proton Proton Collider (SPPC)

Textbooks and Reading Material

1. Accelerator Physics (3rdedition), S. Y. Lee, *World Scientific Publishing* (2012).
2. An Introduction to the Physics of High Energy Accelerators, D. A. Edwards and M. J. Syphers, *John-Wiley & Sons* (2008).
3. Introduction to the Physics of Particle Accelerators, Mario Conte and William W Mackay, *World Scientific* (1991).
4. Particle Accelerator Physics, Helmut Wiedemann, *Springer* (1993).

Teaching Learning Strategies

1. The instructor will detail out the concepts particle acceleration
2. The students will practice the accelerator concepts by solving exercise problems in the recommended books

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	**Course Code**	CPHY 461	**Credit Hours**	3
Course Title	**Relativity and Cosmology**				

Course Introduction

The course introduces special and general relativity and basic cosmology at undergraduate level.

Learning Outcomes

On the completion of the course, the students will:

1. Study basic principles of special and general relativity.
2. Cover the related mathematical concepts.
3. Study some basic application of relativity to Black-hole physics and cosmology.

Course Content

Week 1	Space-Time Formalism of Special Relativity
	Lorentz Transformation
Week 2	Minkowski spacetime and the light-cone line element
	Four-Vectors, Four Velocity and Momentum
Week 3	(Problem Solving)
	Relativistic Kinematics
Week 4	Force Equation in Relativity
	Law of Conservation of 4-Momentum
Week 5	(Problem Solving)
	Covariant Form of Maxwell's Equations: Four-vector potential
Week 6	Field Stress Tensor
	Maxwell's Equation in Covariant Form.
Week 7	(Problem Solving)
	Curved Manifold
Week 8	Contravariant and Covariant Vectors,
	the Metric
Week 9	Geodesics and the Geodesic Equation
	The Christoffel Symbols
Week 10	Curvature

	Covariant Derivative
Week 11	Parallel Transport
	The Riemann Curvature Tensor
Week 12	Ricci Tensor
	General Relativity: Principle of Equivalence
Week 13	Tidal Gravitational (Newtonian) Forces
	Einstein's Field Equations
Week 14	Introducing the Schwarzschild Metric (without fully deriving it as a Solution to the Einstein Field Equation).
	Experimental proves general relativity.
Week 15	Expansion of the universe and Hubble's law
	Freidman equations
Week 16	Black hole
	Hawking radiation

Textbooks and Reading Material

1. Gravity, An Introduction to Einstein's General Relativity, James B. Hartle, *Addison-Wesley* (2003).
2. Introducing Einstein's Relativity, R. D'Inverno, *Oxford University Press* (1992)
3. Dynamics and Relativity, W. D. McComb, *Oxford University Press* (1999)
4. A First Course on General Relativity, Bernard Schutz, *Cambridge University Press* (2009).
5. Relativity Demystified, David McMahon, *McGraw-Hill,* (2006).

Teaching Learning Strategies

The instructor is required to make use of Mathematica/Maple/Python to teach the concepts through visualization/antimutation and symbolic/numerical calculations. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Programme	BSCP	Course Code	CPHY 462	Credit Hours	3
Course Title	**Astrophysics**				

Course Introduction

1. Astrophysics describes the features of objects in the Solar System (i.e. Sun, planets, moons, asteroids, comets, planetary interiors, atmospheres, etc.) and giving details about similarities and differences among these objects.
2. It demonstrates an understanding of the basic characteristics of the Sun and other stars
3. It explains stellar evolution (i.e. red giants, supernovas, neutron stars, pulsars, white dwarfs and black holes) based on evidence and presently accepted theories.
4. It also explains the evolution of the expanding Universe using concepts of the Big Bang.

Learning Outcomes

On the completion of the course, the students will:

1. have understanding of the basic properties of the Sun and other stars
2. be able to Explain stellar evolution
3. be able to Explain the evolution of the expanding Universe based on the concepts of the Big Bang and astronomical features

Course Content		Assignments/Readings
Week 1	Introduction and overview of astrophysics and its scope	
	Telescopes, Detectors, Instruments,	
Week 2	Satellites, Matter and Radiation,	
	Interstellar medium, collapse of gas clouds	
Week 3	Jeans criterion, Star formation and Stellar structure,	
	Nuclear reactions, Hydrostatic equilibrium,	
Week 4	Hydrostatic equilibrium,	
	Virial theorem, Stars masses,	
Week 5	Stellar atmospheres,	
	Energy transport via radiation and convection,	
Week 6	Atomic transitions, chemical abundances,	
	Properties of Stars and their spectra,	

Week 7	Stellar dynamics	
	Evolution and final stages,	
Week 8	Phenomenology of stars, magnitudes, colors,	
	Spectra, distances, radii, temperatures	
Week 9	luminosities, binaries,	
	Gravitational, thermal, nuclear time scales.	
Week 10	Ages of star, Metallicities,	
	Evolution on the Main Sequence,	
Week 11	Stellar evolution beyond the main sequence,	
	AGB stars	
Week 12	HR Diagram,	
	Binary Stars and Accretion Processes,	
Week 13	Fate of Massive Stars, Supernova,	
	Types of supernova,	
Week 14	Degenerate matter,	
	Stellar remnants, white dwarfs,	
Week 15	Brown Dwarf, Neutron stars	
	Black holes, pulsars,	
Week 16	Gamma-ray bursts,	
	Planetary Nebulae, , X-ray binaries	

Textbooks and Reading Material

1. An Introduction to Modern Stellar Astrophysics, D.A. Ostlie, B.W. Carrol, AddisonWisley Publishing Company, Inc., 1996.

2. Nucleosynthesis and Chemical Evolution of Galaxies, B.E.J. Pagel, Cambridge Uni. Press, 1997.

3. Astrophysics for Physicists, Choudhuri AR., Cambridge University press; 2010

Teaching Learning Strategies

1. The instructor is required to deliver concept and knowledge of the subject through lecture based instructional approach and discussions.
2. Students are required to solve related problems, exercises and questions given in the main text books

Assignments: Types and Number with Calendar
At least two assignments and two quizzes

Assessment			
Sr. No.	**Elements**	**Weightage**	**Details**
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	Course Code	CPHY 473	Credit Hours	3
Course Title	**Non-linear Physics**				

Course Introduction

This course encloses basic understandings about the nonlinear interacting physical systems, their integrability without approximations and their physical applications.

Learning Outcomes

1. Physical understanding of non-linear interacting systems.
2. Physical features of solitons from application point of view (nonlinear optical fibre)
3. Learn the related application to chaotic systems.

Course Content

Week 1	Introduction to nonlinear physical systems
	Nonlinear oscillators, Pendulum, Duffing oscillator
Week 2	Van der Pol oscillator, Forced nolinear oscillators
	Determination of dynamical systems and state space
Week 3	Classifications of dynamical systems
	Chaos and randomness
Week 4	Fractals and Solitons
	Dissipative versus conservative dynamical systems
Week 5	Stability analysis
	De-dimesionalization and examples
Week 6	Lyapunov exponents
	Chaos in the logistic map,
Week 7	The Lorenz model
	Invariants, Attractors
Week 8	Bifurcation
	chaotic attractors Models and applications
Week 9	Simulations and scaling
	Origin of soliton, Types of solitons
Week 10	Derivation of solitoinc equation

	The KdVsolitons
Week 11	Coupling oscillators,
	Periodic solutions : soliton trains
Week 12	Solitary wave solutions
	Nonlinear Riccati equation
Week 13	Nonlinear Schrodinger (NLS) equations
	Hamiltonian formalism
Week 14	Mechanical linearization
	Solitonic solutions of NLS equation
Week 15	Bright and dark solitons
	Integrable approaches for solitary wave solutions
Week 16	Stability analysis
	Symmetries reduction of soliton equations

Textbooks and Reading Material

Recommended Books:

1. An Introduction to Nonlinear Physics, Liu Lam, Springer, New York (2003)
2. Nonlinear Partial Differential equations for Scientists and Engineers, L. Debnath, *Springer* (1997).
3. Darboux Transformations in Integrable Systems, GuChaohao, Hu Hesheng, Zhou Zixiang*Springer* (2005).
4. Solitons: An Introduction, P. G. Drazin and R. S. Johnson, *Cambridge University Press* (1989).
5. The Direct Methods in Soliton Theory, R. Hirota, *Cambridge University Press* (2004).
6. Mechanics, From Newton's Laws to Deterministic Chaos, (6th edition) *Springer, Florian Scheck* (2018).

Teaching Learning Strategies

The instructor is required to make use of Mathematica/Maple/Python to teach the concepts through visualization/antimutation and symbolic/numerical calculations. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
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Course Outline

Program	BSCP	**Course Code**	CPHY 474	**Credit Hours**	3
Course Title	**Introduction to soliton theory with applications**				

Course Introduction

This course encloses the understandings about the integrable methods, Interactions of solitons, Symmetries, advanced mathematical tools in nonlinear physics, applications of solitons and introduction to Quantum Integrable systems.

Learning Outcomes

1. Physical understanding of non-linear and higher order space derivative in nonlinear field equations
2. Geometrical and Physical Aspects of soliton propagation
3. Mathematical Modeling of soliton equations from application point of views
4. The derivation of Quantum analogues of Classical Integrable Systems

Course Content

Week 1	Advanced integrable methods in nonlinear physics
	Linear Representation of nonlinear field equations
Week 2	Basic Introduction of Darboux Transformations
	Darboux solutions of some solitonic equations as KdV equation and NLS equation
Week 3	Multi-soliton solutions and their interaction profiles
	Generalization of N-fold multi-soliton solutions in Determinant form
Week 4	Symmetries and Conserved quantities associated to soliton equations
	Introduction of Painlevé equations as ordinary reductions of nonlinear field equations
Week 5	Introduction to Backlund Transformation: Principle of nonlinear superposition
	Backlund Transformation: Examples of some nonlinear field equations
Week 6	Painlevé Second Equation
	Airy' s solutions of Painlevé Second Equation
Week 7	Polynomial solutions
	Polynomial solutions
Week 8	Connection of Painlevé second equation with KdV equation and NLS equation
	Applications of integrable models
Week 9	Nonlinear Optical Fibre

	Fluid dynamics
Week 10	Gravitational waves and solitons
	Gravitational waves and solitons
Week 11	Nonlinear dispersive semiconductor materials
	Energy propagation through inhomogeneous dispersive medium
Week 12	Higher order interactions: Nonlinear Klein Gordon model
	Higher order interactions: Nonlinear Klein Gordon model
Week 13	Hirota Bilinear forms of Nonlinear Field equations
	Hirota Bilinear forms of Nonlinear Field equations
Week 14	Hirota Bilinear forms: **Multi-soliton solutions**
	Physical analysis on permanent profile and particle like solutions of nonlinear field equations under interactions and collisions
Week 15	Physical analysis on permanent profile and particle like solutions of nonlinear field equations under interactions and collisions
	Physical analysis on permanent profile and particle like solutions of nonlinear field equations under interactions and collisions
Week 16	Introduction to quantum Integrable systems
	Derivations of some quantum integrable systems through Lax pair

Textbooks and Reading Material

Recommended Books:

1. An Introduction to Nonlinear Physics, Liu Lam, Springer, New York (2003)
2. Nonlinear Partial Differential equations for Scientists and Engineers, L. Debnath, *Springer* (1997).
3. Darboux Transformations in Integrable Systems, GuChaohao, Hu Hesheng, Zhou Zixiang*Springer* (2005).
4. Solitons: An Introduction, P. G. Drazin and R. S. Johnson, *Cambridge University Press* (1989).
5. The Direct Methods in Soliton Theory, R. Hirota, *Cambridge University Press* (2004).
6. Mechanics, From Newton's Laws to Deterministic Chaos, (6th edition) *Springer, Florian Scheck* (2018).

Teaching Learning Strategies

The instructor is required to make use of Mathematica/Maple/Python to teach the concepts through visualization/antimutation and symbolic/numerical calculations. The students are required to solve a large portion of related exercises/questions/problems of the main textbooks.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.

2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre for High Energy Physics
Faculty of Science
University of the Punjab, Lahore

Course Outline

Program	BSCP	**Course Code**	CPHY 474	**Credit Hours**	3
Course Title	**Group Theory for Physics**				

Course Introduction

Course is concentrated on groups like on finite groups and Lie groups, and it is not just the groups themselves that are of interest, but also their linear representations. It will provide a more comprehensive introduction to group theory for beginning under graduate students in physics, and related fields.

Learning Outcomes

On successful completion of this course students will:

1. Understand group and their characteristics required for developing group theory
2. Be able to find the reason mathematically, to write simple proofs, and can judge when an attempted proof in group theory is correct/complete or is not.
3. have a chance to reflect on doing mathematics, solving problems for physics

Course Content		Assignments/Readings
Week 1	Elements of Group Theory: Binary Operation: Groups	Problems
	Order of a group, Order of an element, Periodic group, Finite and infinite group	Problems
Week 2	Cayley table, Cyclic group, Power of an element	
	Cosets, Conjugate elements and Conjugate classes	
Week 3	Conjugate subgroups, Normal subgroups,	
	Quotient group modulo normal subgroup, Centre of a group, Permutation Groups	
Week 4	Lagrange's theorem, Kernal, Homomorphism	
	Isomorphism, First isomorphism theorem	
Week 5	Second isomorphism theorem, Third isomorphism theorem	
	Automorphism, Inner and outer automorphism	
Week 6	Complete group, Conjugation as an automorphism	
	Commutator	
Week 7	Direct product of Groups	

	Direct product of subgroups	
Week 8	Group Representation	
	Unitary Representation	
Week 9	Equivalent Representation	
	Reducible and Irreducible Representation	
Week 10	Complex Conjugate and Adjoint Representation	
	Construction of Representation by Addition	
Week 11	Analysis of Representation	
	Matrix Representation and Invariant Subspaces	
Week 12	Continuous Group	
	Continuous Group	
Week 13	Groups of Linear Transformations	
	General Linear Group	
Week 14	Special Linear Transformation Group	
	And its Applications	
Week 15	Order of a Group of Transformations	
	Lie Groups	
Week 16	Continuous Group as a Lie Group	
	Non-abelian Lie Group	

Textbooks and Reading Material

1. Group theory for Physical Application by Dr M Ayub (1996), University Grant Commission

2. Group Theory for High Energy Physics by Dr M Saleem (2013) , CRC Press

Teaching Learning Strategies

1. Project-Based Learning
2. Inquiry-Based Learning
3. Blended Learning
4. Cooperative Learning

Assignments: Types and Number with Calendar

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes: Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.
3.	Final Assessment	40%	Written Examination at the end of the semester. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development, field work and report writing etc.

Centre For High Energy Physics
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Course Outline

Program	BSCP	**Course Code**	CPHY 484	**Credit Hours**	3
Course Title	**Computational Fluid Dynamics**				

Course Introduction

The course is aimed to provide students with the essential concepts of CFD so that they can develop algorithms and their CFD code. A strong emphasis is given to the understanding and application of underlying methods for solving various CFD problems.

Learning Outcomes

The course introduces the subject of scientific computing. Its objectives are as following.

1. Develop a solid understanding of the fundamental principles, equations, and governing laws of fluid.
2. Understand the application of the finite volume method to numerically solve fluid flow problems.
3. Learn the techniques and tools required for generating appropriate computational meshes for CFD simulations.

Course Content

Week 1	Comparison of Experimental, Theoretical and Computational Approaches
	Why CFD?
Week 2	CFD as a Research and Design Tool
	What is CFD and some Applications (Automobile, Industry, Civil, Environmental etc)
Week 3	Real and Ideal Fluids
	Newton;s Law of Viscosity Viscosity
Week 4	Laminar and Turbulent Flows
	Compressible and Incompressible Fluids
Week 5	Steady and Unsteady Flows
	Models of Flows
Week 6	Divergence of Velocity
	Continuity Equation
Week 7	Momentum Equation
	Energy Equation
Week 8	Navier-Stokes Equations
	Physical Boundary Conditions

Week 9	Physical Classification of PDEs
	Equilibrium Problems
Week 10	Marching Problems
	Mathematical Classification of PDEs
Week 11	Finite Difference (Forward, backward and Central)
Week 12	Errors, Consistency and Stability
Week 13	Difference Equations
Week 14	Explicite and Implicite Approaches
Week 15	Conservative Property
Week 16	Errors and Solution Stability

Textbooks and Reading Material

1. Frank M. Whate: Viscous Fluid Flow, 3rd Edition, McGraw-Hill, 2006
2. J. D. Anderson: Computational Fluid Dynamics: The Basics with Applications, McGraw Hill, 1995.
3. Richard H. Pletcher, John C. Tannehill, Dale A. Anderson: Computational Fluid Mechanics and Heat Transfer, 3rd edition, CRC Press, Boca Raton, 2013.

Teaching Learning Strategies

The instructor is required to make use of FORTRAN/C/C++/Mathematica/Python/C# to teach the concepts through visualization/antimutation. The students are required to solve a large portion of related applications.

Assignments: Types and Number with Calendar

At least two assignments and two quizzes. A course project may also be assigned.

Assessment

Sr. No.	Elements	Weightage	Details
1.	Midterm Assessment	35%	Written Assessment at the mid-point of the semester.
2.	Formative Assessment	25%	Continuous assessment includes Classroom participation, assignments, presentations, viva voce, attitude and behavior, hands-on-activities, short tests, projects, practical, reflections, readings, quizzes etc.

3.	Final Assessment	40%	Written Examination at the end of the semester. At least fifty percent of the question paper would involve new problems related to the concepts learned in the course. It is mostly in the form of a test, but owing to the nature of the course the teacher may assess their students based on term paper, research proposal development and report writing etc.