

Proposal for Minor Revisions to the IPh.D. and M.Sc. Physics Curricula

Rationale for revision

The IPh.D. program in Physics was initiated in 2015, followed by the launch of the M.Sc. Physics program in 2017. During the initial years, the limited number of faculty members constrained the breadth of courses and topics that could be offered. As a result, certain core areas of physics were either not introduced or could not be covered with the desired depth. With the subsequent expansion of faculty strength and expertise, the department is now well positioned to address these gaps and strengthen the academic framework of both programs. Over the years, we have gained valuable experience regarding the academic preparedness of students and the realistic extent of content that can be effectively delivered and assimilated within a single semester. It has been observed that some core courses currently contain excessive content, which compromises the intended rigor and depth of learning. In particular, the learning outcomes of certain 4-credit courses have not consistently met expectations due to overextended syllabi. To address these concerns, we propose a modest restructuring of credits and selective rationalization of course content. Some advanced or specialized topics currently included in core courses may be more appropriately offered as higher-level electives, especially now that the department has sufficient faculty expertise to support such offerings. This approach will allow core courses to focus on foundational principles while enabling motivated students to explore advanced topics through elective options. Additionally, the proposed revisions incorporate constructive suggestions provided by the Progress Review Committee of SPS. The overall objective of these minor modifications is to enhance academic rigor, improve learning outcomes, ensure better content balance, and strengthen the core foundations of both the IPh.D. and M.Sc. programs without altering their fundamental structure.

Credit structure

	MSc (credits)	IPhD (credits)
Core	59	71
Elective	21 (Free elective-9)	18 (Free elective-3)
Total	80	89

No changes have been proposed for overall credit structures of IPhD and MSc.

Proposed revisions

1. **Credit redistribution:** slight modification of the semester-wise credit distribution (*see attached documents*)
2. **Addition of core course:** Nuclear and Particle Physics (3 credits)
3. **Credit reduction of courses:** Mathematical Physics, Classical Mechanics, Electromagnetic Theory, Statistical Mechanics

One credit is reduced for each of these 4-credit courses and appropriate content redistribution is done in these courses.

IIT Mandi

Proposal for a Revised Course

Course number : PH 511
Course Name : Mathematical Physics
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for B.Tech. 3rd and 4th Year.
Prerequisite : Undergraduate physics courses
Mutual Exclusion : NA

1. Preamble:

Mathematical physics provides a firm foundation in various mathematical methods developed and used for understanding different physical phenomena. This course provides mathematical tools to address formalisms used in the core course of master's level physics program.

2. Course Modules with quantitative lecture hours:

1. Graphical Analysis and Vector Calculus Review

Two-dimensional plots of simple functions, Review of Vector Calculus in Curvilinear coordinates. [4 lectures]

2. Linear Vector Spaces

Linear vector spaces, Gram-Schmidt orthogonalization, Self -adjoint, Unitary and Hermitian Operators, Transformation of Operators: Unitary and Similarity Transformations, Eigenvalue Equation, Hermitian Matrix Diagonalization, Dirac Delta function, Infinite-dimensional Vector Spaces, Hilbert spaces. [11 lectures]

3. Ordinary Differential Equations

Review of Second order Linear ODE, Series Solution: Frobenius Method, Inhomogeneous linear ODE, Sturm Liouville equation, Hermitian operators: Eigenvalue Problem. [8 lectures]

4. Special Functions

Bessel, Neumann, Hermite, Legendre, Spherical Harmonics, Laguerre, Gamma and Beta functions. [5 lectures]

5. Complex Analysis

Cauchy- Riemann conditions, Cauchy's Integral theorem, Laurent expansion, Singularities, Calculus of residues, evaluation of definite integrals. [9 lectures]

6. Fourier Analysis

Fourier Series general properties and application, Integral transform, Properties of Fourier transform, Laplace transform, Convolution theorem. [5 lectures]

Laboratory/practical/tutorial Modules: No

3. Text books:

1. Arfken and Weber, Mathematical methods for physicists (Elsevier Academic Press, 7th edition, 2012)
2. Mary L Boas, Mathematical Methods in Physical Sciences, (Wiley 3rd edition, 2005)

4. References:

1. V. Balakrishnan, Mathematical Physics with Applications, Problems and

Solutions(Ane Books, 2023): *Discussion of plotting of functions, Compact discussion of linear vector spaces*

2. K. F. Riley and M. P. Hobson, *Mathematical Methods for Physics and Engineering: A Comprehensive Guide* (Cambridge India South Asian Edition, 2009)
3. J. Mathews and R. L. Walker, *Mathematical Methods for Physicists* (Imprint, New edition 1973)
4. F.W. Byron and R.W. Fuller, *Mathematics of Classical and Quantum Physics* (Dover Publication, New edition, 1992)
5. P. M .Morse and H. Freshbach, *Methods of theoretical Physics Vol. I and II* (Mc-GrawHill, 1953)
6. E. Kreyszig, *Advanced Engineering Mathematics*(Wiley India Private Limited, 10th edition, 2003)
7. P .Dennery and A. Krzywicki,*Mathematics for Physicists*(Dover Publications Inc. 1996)
8. M. Spiegel, *Complex Analysis* (McGraw-Hill Education, 1980)
9. M. Spiegel, *Vector Analysis* (McGraw-Hill Education, 2nd Edition, 2016)

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 512
Course Name : Classical Mechanics
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for B.Tech. 3rd and 4th Year.
Prerequisite : Undergraduate Mechanics course
Mutual Exclusion : None

1. Preamble:

Classical mechanics lies in the foundation of the mechanics of the observable world. Starting from Newtonian mechanics, this course looks into the conservation laws of mechanics, which helps to develop the analytical mechanics in terms of the generalized coordinates. The course looks into Lagrangian and Hamiltonian formalism and the framework of solvable models such as two-body, rigid-body, and small oscillations. Then, we look into the canonical transformation and associated algebraic framework required for the advanced formulation of the mechanics. This course is at an advanced level with more mathematical proofs that enhance the basic introduction to classical mechanics in the undergraduate level.

2. Course Modules with quantitative lecture hours:

Unit/Topic 1: Introduction: Mechanics of a system of particles, constraints, Lagrange's equation motion, Hamilton's principle and calculus of variations, Applications of the Lagrangian Formulation. Symmetries and conservation laws. **(10 hours)**

Unit/Topic 2: The Central Force Problem: The Equivalent one-dimensional problem and classification of orbits, the Kepler problem. **(6 Hours)**

Unit/Topic 3: The Kinematics of Rigid Body motion: Orthogonal transformations, Euler's theorem on the motion of a rigid body, finite rotations, infinitesimal rotations, rate of change of a vector, Angular momentum and kinetic energy of motion, the inertia tensor and the moment of inertia, Euler equation of motion of the rigid body. **(8 Hours)**

Unit/Topic 4: Oscillations: Formulation of the problem, the eigenvalue equation and the principal axis transformation, small oscillations, frequencies of free vibration, and normal coordinates. **(4 hours)**

Unit/Topic 5: The Hamilton Equations of Motion: Legendre Transformations and the Hamilton Equations of Motion, Cyclic Coordinates and Conservation Theorems, The Principle of Least Action. **(6 Hours)**

Unit/Topic 6: Canonical Transformations: The examples of canonical transformation Poisson Bracket and canonical invariants, Liouville's theorem. Hamilton-Jacobi theory and Action-Angle Variables **(8 Hours)**

Laboratory/practical/tutorial Modules: None

3. Textbooks:

1. H. Goldstein, Classical Mechanics, 3e, Pearson Education; 3rd edition (2011), India.

2. References:

1. C. Lanczos, The variational principles of mechanics, Dover Publications; New edition (1986), US.
1. N.C. Rana and P.S. Joag, Classical Mechanics, McGraw Hill Education, India.
2. L.D. Landau and E.M. Lifshitz, Mechanics; Third edition (1 January 2010), Elsevier, India.
3. John R Taylor Classical Mechanics, University Science Books (2005) US.

4. Similarity with the existing courses: None

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 513
Course Name : Quantum Mechanics I
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for B.Tech. 3rd and 4th Years.
Prerequisite : Undergraduate core physics courses
Mutual Exclusion : None

1. Preamble: This course is an introductory postgraduate level course on quantum mechanics covering its basic principles. Several applications of quantum mechanics will be discussed to train students to apply these ideas to model systems in both one and higher dimensions. The course begins with a review discussion of Schrodinger formalism complemented with applications. Dirac notation will be introduced. Applications of quantum mechanics in three dimensions will be discussed. Approximation techniques such as WKB and time-independent perturbation theory will be also discussed in this course.

2. Course Modules with quantitative lecture hours:

Unit/Topic 1:

Review of Schrodinger formalism with applications in 1D, Dirac notation, linear vector operators, matrix representation of states and operators, Ehrenfest theorem, commutator relations in quantum mechanics and uncertainty relations Subtopics **(12 Hours)**

Unit/Topic 2:

Theory of angular momentum in quantum mechanics, commutator relations in angular momentum, Eigen values and Eigen states of angular momentum, spin-angular momentum. **(9 hours)**

Unit/Topic 3:

Application of Schrodinger equation in 3-D models, symmetry and degeneracy, central potentials, Schrodinger equation in spherical co-ordinates, solution to hydrogen atom problem. **(9 hours)**

Unit/Topic 4:

Schrodinger and Heisenberg pictures, Heisenberg equation of motion, Interaction picture, WKB method, Time independent non-degenerate and degenerate perturbation theory with applications. Fine structure, Zeeman effect and hyperfine splitting of one-electron systems **(12 hours)**

Laboratory/practical/tutorial Modules: No

3. Text books:

1. D J Griffith, Introduction to quantum mechanics-(Pearson, Fourth edition, 2015).
2. Claude Cohen-Tannoudji, B Diu, F Laloe, Quantum Mechanics -Vol.1, (Wiley, Second edition 2020).

3. R Shankar, Principles of Quantum Mechanics - (Plenum Press, Second edition, 2011)

4. References:

1. Modern Quantum Mechanics - J J Sakurai (Pearson Edn., revised edition, 1994)
2. Quantum Mechanics Concepts and Applications – N Zetilli (2nd edition 2009)
3. The Feynman Lectures in Physics, Vol. 3, R.P. Feynman, R.B. Leighton, and M. Sands (Narosa Publishing House, 1992).
4. Practical Quantum Mechanics - Siegfried Flügge (Springer 1994)
5. Quantum Mechanics- P. C. Deshmukh(Cambridge University Press 2023)

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 514
Course Name : Electronics
Credit : 3
Distribution : 3-0-0-3
Intended for : M.Sc. and I-Ph.D. in Physics
Prerequisite : None
Mutual Exclusion: NA

1. Preamble: This course aims to provide students with a comprehensive understanding of the principles of electronic devices, circuits, and instrumentation techniques that are widely used in modern physics laboratories and scientific measurements. It introduces the theoretical foundations of analog, digital, frequency-domain, and mixed-signal electronics, with emphasis on their operating principles, characteristics, and applications in physical science experiments. The course is intended to develop the conceptual framework required to understand electronic systems used in instrumentation and measurement, thereby enabling students to interpret, analyze, and apply electronic concepts in advanced studies and research in physics and related areas.

2. Course Modules with quantitative lecture hours:

Unit/Topic 1:

Amplifiers: BJT, Classification of Amplifiers, Cascading of amplifiers, Types of power amplifiers, Amplifier characteristics, Feedback in amplifiers, Feedback amplifier topologies, Effects of negative feedback. [10 lectures]

Unit/Topic 2:

Oscillators and Multivibrators: Classification and basic principle of an oscillator, Feedback oscillator's concepts, Types of oscillators. [4 lectures]

Unit/Topic 3:

Field effect transistors: JFET, FET parameters, MOSFET. [3 lectures]

Unit/Topic 4:

Operational amplifiers: OPAMPs, OPAMP applications. [2 lectures]

Unit/Topic 5:

Boolean algebra and Digital circuit: Number systems, Boolean algebra, De Morgan's theorem, Logic Gates, Karnaugh Maps [6 lectures]

Unit/Topic 6:

Combinational circuits: Adder, Multiplexer, DE multiplexer, Encoder, and Decoder. [5 lectures]

Unit/Topic 7:

Clock and timing circuit: Clock waveform, Schmitt Trigger, 555 Timer [2 lectures]

Unit/Topic 8:

Sequential circuits: Flip-Flops, Registers, Counters, D/A and A/D conversions [10 lectures]

Laboratory/practical/tutorial Modules: No

3. Text books:

- 1) Millman and Halkias, Integrated electronics: McGraw-Hill, (2001).
- 2) A. P. Malvino and D. P. Bates Electronic Principles: (7th Edn) McGraw-Hill (2006).

4. References:

- 1) D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications: (6th Edn), Tata McGraw Hill (2007).
- 2) A. K. Maini, Digital Electronics-Principles, Devices and Applications: John Wiley & Sons (2007).

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 515P
Course Name : Physics Laboratory
Credit : 3
Distribution : 0-0-5-3
Intended for : I-Ph.D. and M. Sc Physics students
Prerequisite : No
Mutual Exclusion : NA

1. Preamble: This experimental course is expected to develop the art of experimentation and analysis skill, understanding the basis of knowledge in physics, and collaborative learning skills among students. Course. The course content includes standard physics experiments from various modules of physics, the theory of which students have learnt during their final year of B. Sc.

2. Course Modules with quantitative lecture hours: No
Laboratory/practical/tutorial Modules:

1. Hall Effect in Semiconductor

Objective: To measure the resistivity and Hall voltage of a semiconductor sample as a function of temperature and magnetic field. The band gap, the specific conductivity, the type of charge carrier and the mobility of the charge carriers can be determined from the measurements.

2. Michelson Interferometer

Objective: To determine the wavelength of the light source by producing interference pattern.

3. Fabry-Perot Interferometer

Objective: To investigate the multibeam interference of a laser light. Also, the wavelength of light source and thickness of a transparent foil can be determined.

4. Zeeman Effect

Objective: To observe the splitting up of the spectral lines of atoms within a magnetic field (normal and anomalous Zeeman effect) and find the value of Bohr's magneton.

5. Diffraction of ultrasonic waves

Objective: To observe Fraunhofer and Fresnel diffraction and determine the wavelength of the ultrasound wave.

6. Frank-Hertz Experiment

Objective: To demonstrate the quantization of atomic energy states and determine the first excitation energy of neon.

7. Fourier optics

Objective: To observe Fourier transformation of the electric field distribution of light in a specific plan.

8. Dispersion and resolving power of a grating

Objective: Determination of the grating constant of a Rowland grating based on the diffraction angle (up to the third order) of the high intensity spectral lines. Determination of the angular dispersion and resolving power of a grating.

9. Geiger-Müller-Counter

Objective: To study random events. Determination of the half-life and radioactive equilibrium. Verification of the inverse-square law for beta and gamma radiation.

10. Scintillation counter

Objective: Energy dependence of the gamma absorption coefficient / Gamma spectroscopy.

11. Four Probe

Objective: To measure the resistivity of a semiconductor at different temperature, finding the band gap.

12. Millikan Oil drop

Objective: To estimate the electrical charge of an electron and also show that charge is quantised in units of e .

13. Magnetoresistance of a semiconductor

Objective: To study the magnetic field dependence of the transverse magnetoresistance of a semiconductor.

14. Thermal conductivity of Teflon

Objective: To determine the thermal diffusivity coefficient of Teflon (an organic solid material) using (a) linear flow of heat and (b) radial flow of heat and estimate its thermal conductivity.

3. Text books:

1. R. A. Dunlop, Experimental Physics, Oxford University Press (1988).
4. J Varma, Nuclear Physics Experiments, New Age Publishers (2001)

4. References:

1. A. C. Melissinos, Experiments in Modern Physics, Academic Press (1996).
2. E. Hecht, Optics, Addison-Wesley; 4 edition (2001)
3. Worsnop and Flint, Advanced Practical Physics for Students Methusen & Go. (1950).
4. E.V. Smith, Manual for Experiments in Applied Physics. Butterworths (1970).
5. D. Malacara (ed), Methods of Experimental Physics, Series of Volumes, Academic Press Inc. (1988).

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 521
Course Name : Electromagnetic Theory
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for B.Tech. 3rd and 4th Years.
Prerequisite : Undergraduate core physics courses
Mutual Exclusion : NA

1. Preamble: This course will develop the concepts of electricity and magnetism at a level suitable for master's students. The course content includes electrostatics and magnetostatics and their unification into electrodynamics, and electromagnetic radiation. The idea of special theory of relativity has been included in classical electrodynamics.

2. Course Modules with quantitative lecture hours:

1. Electrostatics and Magnetostatics in Vacuum

Review of electrostatics and magnetostatics, Laplace and Poisson equations, Boundary Value Problems in Electrostatics, Method of Images, Electrostatic and magnetostatic energy. **(7 lectures)**

0. Electrostatics and Magnetostatics in Matter

Multipole Expansions, Dielectrics and Magnetization, Field inside cavity, Clausius-Mossotti equation. **(7 lectures)**

0. Maxwell equations

Maxwell Equations, gauge symmetry, Electromagnetic energy and momentum, Conservation Laws. **(6 lectures)**

0. Electromagnetic Waves

Waves in one dimension, reflection, refraction and polarization, Electromagnetic waves in vacuum, Electromagnetic Waves in dispersive media, Absorption and Dispersion, Waveguides. **(11 lectures)**

0. EM Radiation

Retarded Potential, Lienard-Wiechart potential, Radiation from accelerated charge, Dipole radiation, Larmor formula. **(7 lectures)**

0. Special Relativity and Electromagnetism

Magnetism as a relativistic phenomenon, Lorentz transformations of electromagnetic field, Lorentz covariance of Maxwell equations. **(4 lectures)**

Laboratory/practical/tutorial Modules:

3. Text books:

1. D.J. Griffiths, Introduction to Electrodynamics 5th ed, CUP (2025)

4. References:

1. J.D. Jackson, Classical Electrodynamics 3rd ed, Wiley(2007)
2. A. Zangwill, Modern Electrodynamics, CUP(2012)
3. K. Milton and J. Schwinger, Classical Electrodynamics, CRC Press(1998)
4. M. Maggiore, A Modern Introduction to Classical Electrodynamics, OUP(2023)

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.	Course Code	Similarity Content	Approx. % of Content
1.	EP321	Part of section 1	20%

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 522
Course Name : Statistical Mechanics
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for others
Prerequisite : Undergraduate thermodynamics
Mutual Exclusion: None

1. Preamble:

Statistical mechanics use probability methods to extend the mechanics to many-body systems for statistical predictions of their collective behavior. This course introduces basic probability theory concepts and, with a thermodynamics review, thus acts as a bridge between thermodynamics and the mechanics of constituent particles. The topics covered include Statistical mechanics of ideal gas systems, harmonic oscillators, spin models, etc., providing the primary functioning of the formalisms of statistical mechanics for ideal systems. Methods of statistical mechanics serve as essential prerequisites to many advanced topics in physics, theoretical chemistry, and engineering that use probabilistic predictions on many-body problems. This course is at an advanced level with more mathematical proofs that enhance the basic introduction of thermodynamics and statistical mechanics at the undergraduate level.

2. Course Modules with quantitative lecture hours:

Unit/Topic 1: Review of Thermodynamics: Laws of Thermodynamics, Carnot cycle, entropy Specific heat, Maxwell relations, Thermodynamic potentials, Ideal gas, Equation of state, van der Waals equations, Gibbs-Duhem relation Thermodynamic stability **(6 Hours)**

Unit/Topic 2: Probability concepts and examples - random variables single and multiple Probability distribution of many variables Binomial distribution and One Dimensional random walk problem - probability distributions and moments. Law of large numbers and Central Limit theorem. Information and entropy. **(6 Hours)**

Unit/Topic 3: Liouville equation-Boltzman ergodic hypothesis, Gibbsian ensemble. Phase space and connection between mechanics and statistical mechanics by thermodynamic equilibrium. Microcanonical ensemble, microstates, and macrostates. Classical ideal gas, phase space volume of the ideal gas. Gibb's Paradox. **(6 Hours)**

Unit/Topic 4: Canonical ensemble, partition function. Helmholtz free energy, Thermodynamics from the partition function. Classical ideal gas- equipartition and Virial theorem. Examples: harmonic oscillator and spin systems, Grand canonical ensemble-density, and energy fluctuations- Gibbs free energy. **(10 hours)**

Unit/Topic 5: Formulation of quantum statistical mechanics density matrix- micro-canonical, canonical, and grand canonical ensembles- Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics - comparison. The density matrix of a two-particle ideal gas - comparison in different statistics. Ideal gas in classical and quantum ensembles. **(6 Hours)**

Unit/Topic 6: Ideal Bose and Fermi systems Examples of ideal quantum gases. Bose-Einstein and Fermi-Dirac functions and approximations. Bose-Einstein condensation, statistics of phonons in ideal solids, Black body radiation, Fermi Energy. **(8 Hours)**

Laboratory/practical/tutorial Modules: None

3. Text books:

1. R K Pathria and Paul D Beale , Statistical Mechanics, Academic Press US , 2011.
2. M Kardar Statistical Physics of Particles Cambridge University Press, UK, 2007.

4. References:

1. Kerson Huag, Statistical Mechanics, Wiley India, India, 2000.
2. Fundamentals of Statistical and Thermal Physics, F Reif, Waveland Press US, 2010.
3. Statistical Physics part I, L D. Landau and E. M. Lifshitz, Elsevier, India 2011.

5. Similarity with the existing courses: None

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 524
Course Name : Atomic and Molecular Physics
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for others
Prerequisite : Basic Quantum Mechanics courses
Mutual Exclusion: None

1. Preamble: This course introduces the basic ideas of atomic and molecular physics. It teaches students how to apply quantum mechanics and extract information from many-electrons atoms and molecules. The course begins with a review of some of the basic concepts in quantum mechanics and then discusses the time-dependent perturbation theory and its applications. It will then proceed to many-electron atomic systems and then to the concepts associated with molecular spectroscopy.

2. Course Modules with quantitative lecture hours:

Unit/Topic 1:

Review of perturbation theory, Atoms in electric and magnetic fields **(8 hours)**

Unit/Topic 2:

Time-dependent perturbation theory and application Fermi- Golden rule, Interaction of electromagnetic radiation with single electron atoms, Rabi flopping, Dipole approximation and dipole selection rules, Transition rates, Line broadening mechanisms, spontaneous and stimulated emissions and Einstein coefficients. **(14 hours)**

Unit/Topic 3:

Variational method and applications, two-electron and alkali systems, central field approximation, Slater determinant, Introduction to self-consistent field method, L-S coupling, J-J coupling, Fine structure and Zeeman effect in the alkali spectra, selection rules, Hyperfine interactions. **(10 hours)**

Unit/Topic 4:

Born Oppenheimer Approximation, Rotational and Vibrational and Raman Spectra of molecules-with examples from diatomic molecules. **(10 hours)**

Laboratory/practical/tutorial Modules: No

3. Text books:

1. Physics of atoms and molecules - Bransden and Joachain (Pearson, second edition, 2011)
2. A Students' Guide to Atomic Physics – M. Fox (Cambridge Univ. Press, 2018 First edition)

4. References:

1. Many-electron theory-S. Raimes (North-Holland Pub. Co.1972)
2. Fundamentals of molecular spectroscopy- C. Banwell and E. Maccash (Mc Graw Hill, 2013)
3. Quantum Mechanics- P. C. Deshmukh (Cambridge University Press 2023)
4. Quantum Mechanics-Merzbacher (Third edition, Wiley, 2011)
5. Quantum mechanics-Landau and Lifshitz (Butterworth-Heinemann Ltd; 3rd Revised edition (18 December 1981)

6. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 612
Course Name : Nuclear and Particle Physics
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for B.Tech. 3rd and 4th Years.
Prerequisite : Quantum Mechanics, Electromagnetic Theory
Mutual Exclusion : NA

1. Preamble:

The objective of the proposed course is to introduce students to the fundamental principles and concepts of nuclear and particle physics. Students will be able to know the fundamentals of the interaction of high-energy particles. This course is expected to provide a working knowledge of real-life problems.

2. Course Modules with quantitative lecture hours:

Properties of Nuclei: Nuclear size, nuclear radius and charge distribution, Rutherford Scattering, mass and binding energy, semi-empirical mass formula, nuclear stability, angular momentum, parity and isospin, magnetic dipole moment, electric quadrupole moment, and nuclear shape. **(5 Lectures)**

Nuclear models: Evidence of shell structure (magic numbers), Liquid drop model, Shell model, ground state spin & parity. **(4 Lectures)**

Two-body problems: Deuteron ground state, excited states, spin dependence of nuclear forces, two-nucleon scattering, charge symmetry and charge independence of nuclear forces, exchange nature of nuclear forces. **(4 Lectures)**

Nuclear decay: Particle decays, Gamow theory of Alpha decay, Fermi theory of Beta decay, Gamma decay, direct evidence for the neutrino. **(5 Lectures)**

Nuclear Reactions: Different types of reactions, Direct & Compound nucleus formation and break-up, nuclear fission, fusion reaction. **(4 Lectures)**

Elementary particles: Fundamental interactions. Particle Zoo: Leptons, Hadrons. Organizing principle: Baryon and Lepton Numbers, Strangeness, Isospin, The eightfold way. Quarks: Colour charge and strong interactions, confinement, Gell–Mann–Nishijima formula, Relativistic kinematics and conservation laws.

The Standard Model: parity violation in weak interaction, Wu's experiment, elementary idea about electroweak unification, quark model, concept of colour charge, discrete symmetries, properties of quarks and leptons, particle interactions, and Feynman diagrams. **(15 Lectures)**

Experimental Techniques and Applications: Particle Accelerators: LINAC, Cyclotron, Synchrotron, Brief overview on present-day accelerators (RHIC, LHC). Particle detectors:

Giger-Muller counter, scintillators, calorimeters, and trackers. Radiation therapy, nuclear medicine, and imaging, dosimetry. **(5 Lectures)**

3. Text books:

4. Kenneth S Krane, Introductory Nuclear Physics, **Vol., Wiley, UK, 2016**
5. David Griffiths, Introduction to Elementary Particles (4th Edition)

4. References:

1. An introduction to the physics of Nuclei and Particles by Richard A Dunlap (2004)
2. Nuclear and Particle Physics: An Introduction by B. R. Martin (2013)
3. Nuclear Physics: Principles and Applications by John Lilley (2001)
4. Modern Particle Physics by Mark Thomson (2013)

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.	NA	NA	NA	NA

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 613
Course Name : Quantum Mechanics II
Credit : 3
Distribution : 3-0-0-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics; Elective for others
Prerequisite : First course on Quantum Mechanics
Mutual Exclusion: None

1. Preamble: This course introduces some of the advanced level topics in quantum mechanics. The course begins a review of some of the basic concepts in quantum mechanics and then discusses the detailed theory of angular momentum algebra. It will then proceed to discuss the concepts in scattering theory.

2. Course Modules with quantitative lecture hours:

Unit/Topic 1:

Review of basic concepts in quantum mechanics, measurements, observables and generalized uncertainty relations, change of basis, generator of translation. **(8 hours)**

Unit/Topic 2:

Angular Momentum: General theory of angular momentum, Angular momentum algebra, Addition of angular momenta, Clebsch-Gordon coefficients, illustration of Wigner-Eckart theorem. **(8 hours)**

Unit/Topic 3:

Symmetries in Quantum Mechanics: Symmetry principles in quantum mechanics, conservation laws and degeneracies, discrete symmetries, parity and time reversal. **(8 hours)**

Unit/Topic 4:

Oscillating dipoles and Bloch sphere representation, Density Operator and Density Matrix formalism, Optical Bloch Equations **(8 hours)**

Unit/Topic 5:

Scattering Theory: Non-relativistic scattering theory. Scattering amplitude and cross-section, Partial wave analysis, optical theorem, Integral equation for scattering, Born approximation. **(10 hours)**

Laboratory/practical/tutorial Modules: No

3. Text books:

1. Modern Quantum Mechanics - J J Sakurai (Addison Wisley, revised edition, 1993).
2. Quantum Mechanics, Cohen-Tannoudji, B Diu, F Laloe (Vol. I and II) (Wiley, second edition 2020)

4. References:

7. Many-electron theory-S. Raimes (North-Holland Pub. Co.1972) 2
8. Quantum Mechanics- P. C. Deshmukh(Cambridge University Press 2023)
9. Quantum Mechanics-Merzbacher (Third edition, Wiley, 2011)

10. Quantum mechanics-Landau and Lifshitz (Butterworth-Heinemann Ltd; 3rd Revised edition (18 December 1981)

11. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 525P
Course Name : Electronics Laboratory Practicum
Credit : 3
Distribution : 0-0-5-3
Intended for : Core for M.Sc. and I-Ph.D. in Physics
Prerequisite : Electronics (PH514)
Mutual Exclusion: NA

1. Preamble: This laboratory course is designed to provide students with hands-on experience in the design, analysis, and implementation of fundamental electronic circuits and systems commonly used in physics and engineering applications. The course introduces practical aspects of analog and digital electronics through experiments. Students will gain experience in constructing and testing circuits such as transistor amplifiers, logic gates, filters, converters, multiplexers, counters, and multivibrators, and will learn the principles of interfacing sensors with microcontroller platforms such as Arduino. Through laboratory exercises and a mini-project, students will develop practical skills in circuit design, measurement, troubleshooting, and instrumentation, enabling them to apply electronic principles to real-life scientific and technological problems.

2. Course Modules with quantitative lecture hours: No

Laboratory/practical/tutorial Modules:

1. To design and use bipolar junction transistors (BJT) as an amplifier and switch, based on common emitter (CE), common collector (CC), and common base (CB) configurations. Verify and draw the IV characteristics.
2. Seven-segment display. Output verification of Logic Gates.
3. Design of Integrator, Differentiator, low pass, and high pass filter using an OpAmp IC 741.
4. Design and verify A/D and D/A converters using OpAmp.
5. Design of 4-bit Multiplexer and Demultiplexer using flip flops.
6. Design of 4-bit Shift registers and Counters using flip flops.
7. Design of Astable and Monostable Multivibrator using IC 555.
8. Development and testing of an Arduino-based sensor circuit: Arduino-Based Sensor Interfacing, Firmware Development, Circuit Design, and Calibration
9. Design of Wein Bridge and Colpitts oscillator.

Project: Developing the working model of an electronic instrument for real-life application.

3. Text books:

- 1) Millman and Halkias, Integrated electronics: McGraw-Hill, (2001).
- 2) A. P. Malvino and D. P. Bates Electronic Principles: (7th Edn) McGraw-Hill (2006).

4. References:

- 1) D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications: (6th Edn), Tata McGraw Hill (2007).
- 2) A. K. Maini, Digital Electronics-Principles, Devices and Applications: John Wiley & Sons (2007).

3) Sedra and Smith, Microelectronic circuits, Oxford publications, sixth edition 2013.

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

IIT Mandi

Proposal for a Revised Course

Course number : PH 611P
Course Name : Experimental Research Techniques
Credit : 4
Distribution : 0-0-7-4
Intended for : Core for M.Sc. and I-Ph.D. in Physics
Prerequisite : No
Mutual Exclusion : NA

1. Preamble: According to Newton's third law, one may simply move the earth down and up just by throwing the ball up and down. But the central question is why don't we feel it? It is because of its immeasurability within the uncertainty of the measuring equipment. Performing an experiment without the knowledge of underlying uncertainty has little meaning. The students will be given a flavour of what it really means by (a) performing an experiment (b) developing a mini experimental setup (c) assembling and engineering tools. Aim of the proposed course is to amalgamate the concepts of physics via assembling, developing mini experiments and building components. Students will get to know about a few advanced concepts through high precision instruments.

2. Course Modules with quantitative lecture hours: No

Laboratory/practical/tutorial Modules:

Unit I (Mandatory)

LabVIEW interfacing: Introduction to data acquisition systems, LabVIEW/open source (such as Python) programming (Interfacing and programming), Signal processing and Error analysis.

Reverse engineering of any vacuum pump: A rotary pump along with its manual will be provided to the students. They have to dismantle this pump and assemble it and learn about its internal parts. This process helps in the development of skills related with assembling (spatial skills).

Skill development for carpentry: Self explanatory

Unit II

A student needs to complete at least 3-4 set of experiments from the following list of experiments.

1. Temperature dependence of electrical resistivity of materials: This experiment involves measuring temperature dependent resistivity of any material using four probe method and Vander Pauw methods. The skills that one will develop are to make fine contacts on the sample, learn the intricacies involved in making this set up.

2. Electronic properties of material using photoemission technique: Photoemission experiments will be done on any material and its electronic properties will be studied. The skills that one will develop are the intricacies involved in conducting experiments in ultra-high vacuum conditions.

3. Seebeck coefficient measurement: Develop mini Seebeck coefficient experiment to distinguish n-type and p-type semiconductors from a mixture of it.

4. Structural properties of materials using powder x-ray diffraction (XRD) technique: To understand structural phase transition of any given material. The skills that

one will develop are to understand the intricacies involved in any diffraction experiment, temperature variation set up, analysis of any powder XRD pattern.

5. Experiments on laser physics: This experiment will be helpful to understand optical pumping, spontaneous emission, induced emission, population inversion, optical resonator, resonator modes etc. The parameters like optimum output coupling, laser threshold and differential efficiency can also be determined. Students will develop skills to handle laser operation by aligning the optical components in the laser cavity.

6. Two slit interference-one photon at a time: This experiment will give hands on familiarity to confront wave-particle duality in a precise and definite way. It will develop the skill of single photon detection and theoretical modelling.

7. Molecular absorption and emission: The objective is to know the nature of molecular spectra by measuring absorption and emission spectra. This will also provide insights into the molecular energy levels and transitions between them. Preparation of molecular solution and data analysis skills will be developed.

8. Design and making of any components: This involves training to make technical drawing, operate lathe for shaping and making any given components.

9. Scanning tunnelling microscope: Introduction to the design and working principle and hands on experiments on atomically thin samples.

10. Magnetic susceptibility of a material as a function of temperature.

3. Text books:

1. Transmission Electron Microscopy, by C. Barry Carter and David B. Williams, Springer, New York (2016).
2. Experimental Techniques in Condensed Matter Physics at Low Temperatures, by Robert C. Richardson and N. Smith ; CRC Press (2018).

4. References: No

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.				

6. Justification of new course proposal if cumulative similarity content is >30%:

NA

Sl. No.	Semester	Type	Course Code	Course Name	L	T	P	C	L - T - P - C	Semesterwise Credits	Credits Completed	Remarks
1	I	Core	PH-511	Mathematical Physics	3	0	0	3	3-0-0-3			
2	I	Core	PH-512	Classical Mechanics	3	0	0	3	3-0-0-3			
3	I	Core	PH-513	Quantum Mechanics I	3	0	0	3	3-0-0-3			
4	I	Core	PH-514	Electronics	3	0	0	3	3-0-0-3			
5	I	Core	PH-515P	Physics Lab	0	0	5	3	0-0-5-3			
6	I	Core	HS-541	Technical Communications	1	0	0	1	1-0-0-1			
7	I	Core	PH-516	Research Project - I	0	0	4	2	0-0-4-2			
8	I	Core	PH-517	Research Project - II (Winter)	0	0	4	2	0-0-4-2			
										20	20	
9	II	Core	PH-521	Electromagnetic Theory	3	0	0	3	3-0-0-3			
10	II	Core	PH-522	Statistical Mechanics	3	0	0	3	3-0-0-3			
11	II	Core	PH-523	Condensed Matter Physics	3	0	0	3	3-0-0-3			
12	II	Core	PH-524	Atomic and Molecular Physics	3	0	0	3	3-0-0-3			
13	II	Core	PH-621	Computational Methods of Physics	2	0	4	4	2-0-4-4			
14	II	Core	PH-614	Seminar and Report	0	0	4	2	0-0-4-2			
15	II	Core	PH-526	Research Project-III	0	0	6	4	0-0-6-4			
16	II	Core	PH-527	Research Project-IV (Summer)	0	0	6	4	0-0-6-4			
										26	46	
17	II	Core	PH-612	Nuclear and Particle Physics	3	0	0	3	3-0-0-3			
18	III	Core	PH-613	Quantum Mechanics II	3	0	0	3	3-0-0-3			
19	III	Core	PH-525P	Electronics Lab Practicum	0	0	6	3	0-0-6-3			
20	III	Core	PH-615P	Mini Thesis - I	0	0	8	4	0-0-8-4			
21	III	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
22	III	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
23	III	Elective		Free Elective	3	0	0	3	3-0-0-3			
										22	68	Can be done in any semester instead of Discipline elective
24	IV	Core	PH-616P	Mini Thesis - II	0	0	16	8	0-0-16-8			
25	IV	Core	PH-611P	Experimental Research Techniques	0	0	8	4	0-0-8-4			
26	IV	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
27	IV	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
28	IV	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
										Minimum 12	Minimum 80	Optional: May finish in V/VI Optional: May finish in V/VI Students need to finish a
29	V	Elective			3	0	0	3	3-0-0-3	minimum 0/maximum		
30	VI	Elective			3	0	0	3	3-0-0-3	minimum 0/maximum €	Minimum 89	Students must finish all 89

Sl. No.	Semester	Type	Course Code	Course Name	L	T	P	C	L - T - P - C	Semesterwise Credits	Credits Completed	Remarks
1	I	Core	PH-511	Mathematical Physics	3	0	0	3	3-0-0-3			
2	I	Core	PH-512	Classical Mechanics	3	0	0	3	3-0-0-3			
3	I	Core	PH-513	Quantum Mechanics I	3	0	0	3	3-0-0-3			
4	I	Core	PH-514	Electronics	3	0	0	3	3-0-0-3			
5	I	Core	PH-515P	Physics Lab	0	0	5	3	0-0-5-3			
6	I	Core	HS-541	Technical Communications	1	0	0	1	1-0-0-1			
7	I	Elective		Discipline elective/Free elective	3	0	0	3	3-0-0-3	19	19	Two Free Elective courses have to be completed. These courses can be taken in any semester.
8	II	Core	PH-521	Electromagnetic Theory	3	0	0	3	3-0-0-3			
9	II	Core	PH-522	Statistical Mechanics	3	0	0	3	3-0-0-3			
10	II	Core	PH-523	Condensed Matter Physics	3	0	0	3	3-0-0-3			
11	II	Core	PH-524	Atomic and Molecular Physics	3	0	0	3	3-0-0-3			
12	II	Core	PH-621	Computational Methods of Physics	2	0	4	4	2-0-4-4			
13	II	Core	PH-614	Seminar and Report	0	0	4	2	0-0-4-2			
14	II	Elective		Discipline elective/Free elective	3	0	0	3	3-0-0-3	21	40	
15	III	Core	PH-612	Nuclear and Particle Physics	3	0	0	3	3-0-0-3			
16	III	Core	PH-613	Quantum Mechanics II	3	0	0	3	3-0-0-3			
17	III	Core	PH-525P	Electronics Lab Practicum	0	0	6	3	0-0-6-3			
18	III	Core	PH-518P	PG Project - I	0	0	8	4	0-0-8-4			
19	III	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
20	III	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
21	III	Elective		Discipline elective/Free elective	3	0	0	3	3-0-0-3	22	62	
22	IV	Core	PH-519P	PG Project - II	0	0	16	8	0-0-16-8			
23	IV	Core	PH-611P	Experimental Research Techniques	0	0	8	4	0-0-8-4			
24	IV	Elective		Discipline Elective	3	0	0	3	3-0-0-3			
25	IV	Elective		Discipline elective/Free elective	3	0	0	3	3-0-0-3	18	80	