MSc Physics

(2 Year program)

Course Structures & Evaluation Plan

Autumn 2019 onwards

Department of Physics,
National Institute of Technology Meghalaya
Shillong-793003, Meghalaya, India
http://nitmeghalaya.in/nitmeghalaya/department/physics-1

Model Plan Semester-wise: MSc Physics Curriculum: Autumn 2019 onwards

Proposed Model Plan				
Semester I				
Course code	Course Name	L-T-P	C	Prerequisites
PH 401	Mathematical Physics-I	3-1-0	4	None
PH 403	Quantum Mechanics-I	3-1-0	4	None
PH 405	Classical Mechanics	3-1-0	4	None
PH 407	Electromagnetic Theory	3-1-0	4	None
PH 409	Basic Analog and Digital Electronics	3-0-0	3	None
PH 481	Electronics Laboratory	0-0-6	3	None
			22	
Semester II				
PH 402	Mathematical Physics-II	3-1-0	4	None
PH 404	Quantum Mechanics-II	3-1-0	4	PH 403
PH 406	Statistical Mechanics	3-1-0	4	None
PH 408	Applied Optics	3-0-0	3	None
PH 422	Computational Programming	1-0-2	2	None
PH 482	General Physics Laboratory	0-0-6	3	None
			20	
Semester III				
PH 501	Atomic and Molecular Physics	3-1-0	4	None
PH 503	Condensed Matter Physics	3-1-0	4	None
PH 505	Nuclear & Particle Physics	4-0-0	4	None
PH 507	Scientific Writing and Seminar	0-0-2	1	None
PH 581	Optics Laboratory	0-0-6	3	None
----	Elective-I	3-0-0	3	None
PH571	Project-Stage I	0-0-4	2	None
			21	
Semester IV				
----	Elective -II	3-0-0	3	None
----	Elective-III	3-0-0	3	None
----	Elective-IV	3-0-0	3	None
PH 572	Project-Stage II (Projects will be assigned at the beginning of Semester III.)	0-0-16	8	None
			17	
Total			80	

Electives	Course Code	Course Name	L-T-P	C	Prerequisites
Elective-I	PH 521	Light-Matter Interaction	3-0-0	3	PH 408
	PH 523	Spintronics	3-0-0	3	PH 403/PH 404
	PH 525	Biological Physics	3-0-0	3	None
	PH 527	Phase Transitions and Critical Phenomena	3-0-0	3	PH 406
	PH 529	Non-equilibrium Statistical Mechanics	3-0-0	3	PH 406
	PH 531	Nanoelectronics	3-0-0	3	PH 403/PH 404
Elective-II	PH 522	Measurement Techniques	3-0-0	3	None

		and Cryogenics			
	PH 524	Numerical Methods & Computational Physics	3-0-0	3	None
Elective-III	PH 526	Non Destructive Testing Lab	0-0-6	3	None
	PH 528	Computational lab	0-0-6	3	None
Elective-IV	PH 542	Science and Technology of Thin Films	3-0-0	3	PH 503
	PH 544	Nanoscience and Technology	3-0-0	3	PH 403/PH 503
	PH 546	Physics of Liquid Crystals	3-0-0	3	None
	PH 548	Advanced Condensed Matter Physics	3-0-0	3	PH 503
	PH 550	Physics for Semiconductor Devices	3-0-0	3	PH 409/PH 503
	PH 552	Quantum Information and Computation	3-0-0	3	PH 403/PH 409

MSc Physics Credit Distribution Semester-wise

Component	No. of Courses	Semester-wise distribution				Total Credit
		I	II	III	IV	
Core Courses	12	5(19)	4(15)	3(12)	---	46
Practical	4	1(3)	2(5)	1(3)	---	11
Departmental Elective	4	---	---	1(3)	3(9)	12
Scientific Writing and Seminar	1	---	---	1(1)	---	01
Project	1+1			1(2)	1(8)	10
Total	23	6(22)	6(20)	7(21)	4(17)	80

**Number of courses (Total Credit)

Course Detail

Program Name	MSc Physics
Duration	2 Year (full time)
Eligibility	(i) B.Sc. (Pass or Hons.) Physics/ Applied Physics with Mathematics as one of the Ancillary subject from UGC recognised Universities (ii) 60% marks (General/OBC), 55% marks in case of SC/ST and PwD Category
Admission	Centralized Counselling through CCMN and Institute Entrance Test for remaining vacant seats
Intake	16

Evaluation Plan

Theory Courses

Assessment task	Type of assessment	Weightage of total assessment in %
Assignment-I	Formative	10 marks (5%)
Class Test – I (1-hour test)	Summative	15 marks (7.5%)
Mid Term (2-hour exam)	Summative	50 marks (25%)
Assignment-II	Formative	10 marks (5%)
Class Test – II (1-hour test)	Summative	15 marks (7.5%)
End Term (3-hour exam)	Summative	100 marks (50%)

Laboratory Courses

Assessment task	Type of assessment	Weightage of total assessment in %
Viva Voce-I	Formative	20 marks (20%)
Lab performance		30 marks (30%)
Viva Voce-2		20 marks (20%)
Lab copy		30 marks (30%)

Dissertation

Assessment task	Weightage of total assessment in %
Report Preparation & Work performance	30 marks (30%)
Seminar Presentation	20 marks (20%)
Viva Voce	20 marks (20%)
Final Report	30 marks (30%)

Total Number of Credit: 80
Core Course: 46
Practical: 11
Project: 10
Departmental Elective: 12
Other Course: 01

PH 401: Mathematical Physics-I (3-1-0:4)

Transformation and Vector Calculus
Vectors in 3-D space, Coordinate Transformations, Rotations in 3D, Differential vector operators, Vector integration, Curvilinear coordinates. **[6L+2T]**

Vector Spaces
Vectors in function spaces - Scalar product, Hilbert space, Schwarz Inequality, Orthogonal expansions, Bessel's inequality, Dirac notation, Gram-Schmidt orthogonalisation, Operators, Basis expansion of operators, Self-adjoint operators, unitary operators, transformation of operators, Invariants. **[9L+3T]**

Ordinary Differential Equations
Introduction, First-Order Equations, ODEs with Constant Coefficients, Second-Order Linear ODEs, Series Solutions - Frobenius' method. **[6L+2T]**

Special Functions
Bessel, Legendre, Hermite and Laguerre functions, Orthogonality, Generating functions, Recurrence relations. **[9L+3T]**

Probability and Statistics
Probability: Definitions, Simple properties, Random variables, Binomial distribution, Poisson distribution, Normal distribution, central limit theorem. **[6L+2T]**

Textbooks and References

1. Arfken, Weber and Harris, "Mathematical Methods for Physicists", 7th edition, Academic Press, 2012.
2. Riley, Hobson and Bence, "Mathematical Methods for Physics and Engineering'', 3rd edition, Cambridge University Press, 2018.
3. M. L. Boas, "Mathematical methods in the Physical Sciences", 3rd edition, Wiley India Pvt. Ltd, 2006.
4. S. D. Joglekar, "Mathematical Physics-The Basics", 1st edition, Universities Press, 2002.
5. V. Balakrishnan, "Mathematical Physics with Applications", Ane Books, 2017.
6. R. Courant and D. Hilbert, "Methods of Mathematical Physics, Vol. 1", 1st edition, Wiley VCH, 1989.
7. P. Dennery and A. Krzywicki, "Mathematics for Physicists", Dover Publications, 2012.
8. R. Beals and R. Wong, "Special Functions: A Graduate Text", Cambridge University Press, 2010.
9. E. Kreyszig, "Advanced Engineering Mathematics", 10th edition, John Wiley & Sons Inc, 2015.

PH 403: Quantum Mechanics-I (3-1-0:4)

Quantum Theory
Empirical basis, wave-particle duality, particle aspect of radiation, wave aspect of matter. **[2L]**

Structure of Quantum Mechanics
Notation of state vector and its probability interpretation, operators and observables, significance of eigenfunctions and eigenvalues, commutation relations, uncertainty principle, measurement in quantum theory. Unitary transformation. **[9L+3T]**

Quantum Dynamics
Time evolution and the Schrödinger equation, Schrodinger, Heisenberg and Interaction representation, position and momentum representation, Expectation values, time-independent Schrödinger equation. **[6L+2T]**

One-dimensional Schrödinger Equation
Free-particle solution, wave packets, particle in a square well potential, transmission through a potential barrier, simple harmonic oscillator by wave equation and operator methods, charged particle in a uniform magnetic field, coherent states. **[6L+2T]**

Wave Mechanics in three dimensions
Separation of variables in spherical polar coordinates, orbital angular momentum, parity, spherical harmonics, free particle in spherical polar coordinates, spherical potential, hydrogen atom, degeneracy and accidental degeneracy. **[6L+2T]**

Angular Momentum and Identical Particles
Rotation operators, angular momentum algebra, eigenvalues of J^2 and J_z, spinors and Pauli matrices, addition of angular momenta. Identical particles, indistinguishability, symmetric and antisymmetric wave functions, incorporation of spin, Slater determinants, Pauli exclusion principle. **[9L+3T]**

Textbooks and References

1. M. Beck, "Quantum Mechanics: Theory and Experiment", 1st edition, Oxford University Press, USA, 2012.
2. N. Zettili, "Quantum Mechanics Concepts and Application", 2nd edition, Wiley India Pvt. Ltd, 2016.
3. John S. Townsend, "A Modern Approach to Quantum Mechanics", 2nd edition, University Science Books, California, 2012.
4. C. C. Tannoudji, B. Diu, and F. Laloe, Quantum Mechanics, Volume 1, 1st edition, Wiley VCH, 1997.
5. E. Merzbacher, "Quantum Mechanics", 3rd edition, John Wiley & Sons, 2011.
6. W. Greiner, "Quantum Mechanics An Introduction", 3rd edition, Springer, 1994.

PH 405: Classical Mechanics (3-1-0:4)

Lagrangian and Hamiltonian Formulations of Mechanics
Calculus of variations, Hamilton's principle of least action, Lagrange's equations of motion, conservation laws, Noether's theorem, systems with a single degree of freedom, Hamilton's equations of motion, phase plots, fixed points and their stabilities. **[9L+3T]**

Rigid Body Dynamics
Euler equations, heavy symmetrical top, precession, nutation. **[3L+1T]**

Two-Body Central Force Problem
Equation of motion and first integrals, classification of orbits, Kepler problem, scattering in central force field, Laboratory and centre of mass frames, Scattering cross section, Rutherford scattering. **[9L+3T]**

Small Oscillations
Linearization of equations of motion, normal modes and normal coordinates, forced oscillations. **[3L+1T]**

Canonical Transformations
Poisson brackets, Hamilton Jacobi theory, Action-angle variables. **[3L+1T]**

Special Theory of Relativity
Postulates of special theory of relativity, Lorentz transformation, Length contraction, Time dilation, Simultaneity, Relativistic kinematics and dynamics, Minkowski Space. **[9L+3T]**

Textbooks and References:

1. H. Goldstein, "Classical Mechanics", 3rd edition, Pearson Education India, 2011.
2. L. D. Landau and E. M. Lifshitz, "Mechanics", 3rd edition, Butterworth-Heinemann, 1982.
3. I. C. Percival and D. Richards, "Introduction to Dynamics", Cambridge University Press, 1982.
4. J. V. Jose and E. J. Saletan, "Classical Dynamics: A Contemporary Approach", Cambridge University Press, 1998.
5. J .R. Taylor, "Classical Mechanics", California University Science Books, 2004.
6. R. Resnick ,"Introduction to Special Relativity", 1st edition, Wiley, 2007.
7. R. Takwale and P. Puranik, "Introduction to Classical Mechanics ", 1st edition, McGraw Hill, 2017.
8. M. R. Spiegel, "Schaum's Outline of Theory and Problems of Theoretical Mechanics: with an Introduction to Lagrange's Equations and Hamiltonian Theory", 1st edition, New Delhi McGraw Hill Education (India) Private Limited, 1980.

PH 407: Electromagnetic Theory (3-1-0:4)

Electrostatics
Coulomb's law, electric field, divergence and curl, applications Gauss's law , electric potential, work and energy, conductor, Laplace equation (1D, 2D and 3D), uniqueness theorem, separation of variables: Cartesian and spherical coordinates, multipole expansion. **[7L+2T]**

Dielectric
Field of an electric dipole, polarization, field of a polarized object, Gauss's law in dielectrics, electric displacement, linear dielectrics, boundary value problems, energy in dielectrics. **[3L+1T]**

Magnetostatics
Introduction, Lorentz force, electric current, equation of continuity, Biot-Savart law and applications, curl and divergence, Ampere's law and applications, magnetic potential, magnetization, field of a magnetized object, Ampere's law in magnetized material, linear and nonlinear media. **[7L+3T]**

Electrodynamics
Electromotive force, Motional emf, Induced Electric Field, Faraday's Law,Inductance, Induced Magnetic Field. **[4L+1T]**

Maxwell's Equations and Solution
The equation of continuity for time-varying fields, inconsistency of Ampere's law, Maxwell's equation, conditions at a boundary surface. Uniform plane wave propagation, solution of a wave equation in the free-space with frequency domain and time domain, wave propagation in conducting medium and dielectric medium, penetration depth and polarisation, reflection by a perfect conductor, perfect dielectric, perfect insulator, surface impedance, transmission line analogy. **[9L+3T]**

Power Flow and Poynting Vector
Poynting's theorem, interpretation of $\vec{E} \times \vec{H}$ instantaneous, average and complex Poynting vector, power loss in a plane conductor. **[6L+2T]**

Textbooks and References

1. D. J. Griffith, "Introduction to Electrodynamics", 4th edition, Prentice Hall India, 2017.
2. J. D. Jackson, "Classical Electrodynamics", 3rd edition, Wiley Eastern, 2007.
3. E. C. Jordan and K. G. Balman, "Electromagnetic Waves and Radiating Systems", 2nd edition, Prentice Hall India, 2015.
4. P. Lorrain, D. R. Corson, and F. Lorrain, "Electromagnetic Fields and Waves", 2nd edition, W.H. Freeman & Company, 1970.
5. M. A. W. Miah, "Fundamentals of Electromagnetics", Tata McGraw Hill, 1982.
6. B. B. Laud, "Electromagnetics", 3rd edition, New Delhi New Age International, 2011.
7. Matthew N.O. Sadiku and S.V. Kulkarni, "Principles of Electromagnetics", 6th Edition, Oxford University Press, 2015.

PH 409: Basic Analog and Digital Electronics (3-0-0:3)

Introduction and Survey of Network Theorems
Thevnin, Norton theorems and network analysis, constant current and constant voltage sources, power supplies, AC and DC bridges, rectifier circuits, transistors at low and high frequencies. **[7L]**

Electronic Devices
Diodes, breakdown in diodes, zener diodes, tunnel diodes, Gunn diode, light-emitting diodes, photo-diodes, negative-resistance devices, p-n-p, n-p-n characteristics, transistors (BJT, JFET, MOSFET, Bipolar). **[8L]**

Integrated Circuit
Large signal and small signal behaviour of bipolar transistors, basic processes in integrated circuit fabrication, bipolar integrated circuit fabrication, MOS integrated circuit fabrication, single stage amplifiers, multistage amplifiers, feedback theory. **[8L]**

Operational Amplifier
Basic differential amplifier circuit, operational amplifier characteristics and applications, simple analog computer, analog integrated circuits, wave shaping circuits, multivibrators. **[5L]**

Digital Electronics
Gates, Boolean algebra, De Morgan's law, combinational and sequential digital systems, flip-flops, counters, registers, memories, multi-channel analyzer, A/D and D/A converters, micro-processors, memory and I/O interfacing, microcontrollers. **[8L]**

Textbooks and References

1. C. K. Alexander and M. N.O. Sadiku, "Fundamentals of Electric Circuits", 6th edition, McGraw Hill Education, 2019..
2. J. Millman and A. Grabel, "Microelectronics", 2nd edition, McGraw Hill, 2017.
3. J. J. Cathey, "Schaum's Outline of Electronic Devices and Circuits", 2nd edition, McGraw Hill, 2002.
4. M. Forrest, "Electronic Sensor Circuits and Projects", Master Publishing Inc, 2006.
5. W. Kleitz, "Digital Electronics: A Practical Approach", 2nd edition, Prentice Hall, 1989.
6. A. Malvino, and D. Bates, "Electronic Principles", 7th Edition, McGraw Hill Education, New Delhi, 2017.

PH 481: Electronics Laboratory-I (0-0-6:3)

1. To study CE amplifier
2. To Study a RC coupled amplifier (two stage amplifier)
3. Op-Amp Arithmetic Operations
    a. adder,
    b. subtractor
    c. integrator
    d. differentiator
4. Op-Amp square, triangle and sawtooth generator using Wien Bridge Oscillator
5. To study signal conditioning circuits using Op-Amp
    a. current to voltage converter
    b. voltage to current converter
    c. voltage to frequency converter
6. To study monostable/astable generators using IC 555 timer
7. To study JK/RS/D Flip flop
8. To study the characteristics of UJT and calculate the relaxation time.
9. To study AD and DA circuits
10. To study and construct the K-map of the given Boolen expression
11. To realize and study the Shift Register. Serial in Serial out/Serial in Parallelout/Parallel in Parallel out/Parallel in Serial out.

References

1. P. B. Zbar and A. P. Malvino, "Basic Electronics: a text-lab manual", 7th edition, Tata McGraw Hill, 2001.
2. D. P. Leach, "Experiments in Digital Principles", 3rd edition, McGraw Hill, 1986.

PH 402: Mathematical Physics-II (3-1-0:4)

Complex Analysis
Analytic functions, Cauchy-Riemann equation, classification of singularities, Cauchy's theorem, Taylor and Laurent expansions, analytic continuation, residue theorem, evaluation of definite integrals. **[9L+3T]**

Integral Transforms
Fourier and Laplace transform, inverse transforms, convolution theorem. Application of solving ODEs and PDEs by transform methods. **[9L+3T]**

Tensors
Tensors in index notation, Kronecker and Levi Civita tensors, inner and outer products, contraction, symmetric and antisymmetric tensors, quotient law, covariant and contravariant tensors, metric tensors, simple applications to general theory of relativity and Klein-Gordon and Dirac equations in relativistic quantum mechanics. **[9L+3T]**

Group Theory
Groups, finite groups, non-Abelian groups, permutation groups, Mapping between groups, subgroups, representation of a group, unitary representations, orthogonality theorem, character table, simple applications to symmetry groups and molecular vibrations. **[9L+3T]**

Textbooks and References

1. S. D. Joglekar, "Mathematical Physics: Advanced Topics", Universities Press.
2. A. W. Joshi, "Matrices and Tensors in Physics", New Age International Private Limited.
3. A. W. Joshi,"Elements of Group Theory for Physicists", New Age International Publishers.
4. Arfken, Weber and Harris, "Mathematical Methods for Physicists", Academic Press.
5. Riley, Hobson and Bence, "Mathematical Methods for Physics and Engineering'', Cambridge University Press.
6. A. Zee, "Group Theory in a Nutshell for Physicists", Princeton University Press.
7. R. J. Beerends, H. G. Ter Morsche, J. C. Van Den Berg, and E. M. Van De Vrie, "Fourier and Laplace Transforms", Cambridge University Press.

PH 404: Quantum Mechanics-II (3-1-0:4)

Symmetries and Conservation Laws
Noether's Theorem, symmetry operations and unitary transformations, conservation principles, space and time translations, rotation, space inversion and time reversal, symmetry and degeneracy.
[10L+3T]

Approximation Methods
Time-independent approximation methods, non-degenerate perturbation theory, degenerate case, Stark effect, Zeeman effect and other examples, Variational methods, WKB method, tunnelling, Time-dependent perturbation theory. **[12L+4T]**

Scattering Theory
Differential cross-section, scattering of a wave packet, integral equation for the scattering amplitude, Greens function, Born approximation, method of partial waves, low energy scattering and bound states, resonance scattering. **[9L+3T]**

Introduction to Relativistic Quantum Mechanics
Klein Gordon equation, Dirac equation, negative energy solutions, antiparticles, Dirac hole theory.
[5L+2T]

Textbooks and References

1. W. Greiner and B. Miller, "Quantum Mechanics: Symmetries", 2nd edition, Springer, 1994.
2. M. Beck, "Quantum Mechanics: Theory and Experiment", 1st edition, Oxford University Press, USA, 2012.
3. R. Shankar, "Principles of Quantum Mechanics", 2nd Edition, Plenum Press, New York, 2010.
4. J. J. Sakurai, "Modern Quantum Mechanics", 2nd edition, Addison Wesley, 2013.
5. W. Greiner, "Relativistic Quantum Mechanics: Wave Equations", 3rd edition, Springer, 2000.

PH 406: Statistical Mechanics (3-1-0:4)

Review of Thermodynamics
Laws of thermodynamics, Carnot's engine, Legendre transformations and thermodynamic potentials, Maxwell relations. **[3L+1T]**

Statistical Description
Macroscopic and microscopic states, connection between statistical and thermodynamics. **[3L+1T]**

Ensemble
Microcanonical ensemble: phase space, Liouville's theorem, applications of ensemble theory to classical and quantum systems; Canonical ensemble : partition function, thermodynamics in canonical ensemble, ideal gas, energy fluctuations, statistics of paramagnetism, negative temperature; Grand canonical ensemble : equilibrium between a system and a particle-energy reservoir, partition function, fluctuations, density matrices. **[9L+3T]**

Theory of Quantum Ideal Gases
Ideal gas in different quantum mechanical ensembles, identical particles, many-particle wave function, occupation numbers, classical limit of quantum statistics, molecules with internal motion. **[6L+2T]**

Bose and Fermi Gases
Ideal Bose Gas: Bose-Einstein condensation, Helium II, blackbody radiation, phonons; Ideal Fermi Gas: Pauli paramagnetism, Landau diamagnetism, White dwarf. **[9L+3T]**

Interacting Systems
Ising model, solution of Ising model in one dimension by transfer matrix method, Mean field theory. **[6L+2T]**

Textbooks and References

1. R. K. Pathria and P. D. Beale, "Statistical Mechanics", Academic Press.
2. S. R. A. Salinas, "Introduction to Statistical Physics", Springer.
3. K. Huang, "Statistical Mechanics", John Wiley Asia.
4. D. Y. Schroeder, "An Introduction to Thermal Physics", Pearson India Education.
5. W. Greiner, L. Neise, and H. Stocker, "Thermodynamics and Statistical Mechanics", Springer.
6. F. Reif., "Fundamentals of Statistical and Thermal Physics", Levant Books.

	National Institute of Technology Meghalaya An Institute of National Importance	CURRICULUM

Programme	**Master of Science in Physics**	Year of Regulation				2019				
Department	**Physics**	Semester				II				
Course Code	Course Name	Credit Structure				Marks Distribution				
		L	T	P	C	INT	MID	END	Total	
PH 408	**Applied Optics**	**3**	**0**	**0**	**3**	**50**	**50**	**100**	**200**	

SYLLABUS

No	Content	Hours	
1	**Potentials and Fields** Potential formulation, scalar and vector potential, gauge transformation, Retarded potential, Jefimenko equations, Lienard-Weichart Potentials, The field of a moving charge, Radiations from dipoles	8	
2	**Lasers and Optics** Interference, Michelson Interferometer, Fabry Perot Interferometer, Diffraction Integral, Basics of Laser, Einstein coefficients, Population inversion, two and three level systems, Total internal reflection and evanescent waves, Polarization states.	8	
3	**Fourier Optics** Spatial frequency, Fourier transform property of lens, spatial-frequency filtering, phase-contrast microscope.	5	
4	**Guided Wave Optics** Waves between parallel planes, transmission line theory. TM and TE waves in rectangular guides, circular waveguide, attenuation factor and Q of waveguides.	6	
5	**Introduction to Optical Fibers** Step index, graded index fibers and applications of optical fibers, photonic crystals, bragg gratings	5	
6	**Anisotropic Media** Plane waves in anisotropic media, uniaxial crystals, and some polarization devices.	4	
	Total Hours	36	

Textbooks and References

A. Ghatak, “Optics”, McGraw Hill.

A. Ghatak & K. Thyagarajan, “Optical Electronics”, New Delhi Cambridge University Press

R. S. Sirohi, “Wave Optics & its Applications”, Orient Longman.

F. L. Pedrotti and L. S. Pedrotti, “Introduction to Optics”, Prentice-Hall International.

J. W. Goodman, “Introduction to Fourier Optics”, McGraw Hill.

E. Hecht & A. R. Ganesan,”Optics”, New Delhi Pearson 2008.

D. J. Griffith, “Introduction to Electrodynamics”, 4thedition, Prentice Hall India, 2017.

PH 422: Computational Programming (1-0-2:2)

Computer languages, C language, algorithms, flow chart, constants and variables, operators and expressions, control statements, looping, functions, arrays, strings, pointers, files in C, preparing and running a C program, problem solving examples in C.

Textbooks and References

1. V. Rajaraman, "Computer Programming in C", PHI Learning.
2. B. Gottfried, "Programming with C", Schaum's Outlines Series.
3. B. W. Kernighan and D. M. Ritchie, "The C programming language", Prentice-Hall.
4. E. Balagurusamy "Programming in ANSI C", 7^{th} Edition, McGraw Hill Education India Private Limited

PH 482: General Physics Laboratory (0-0-6:3)

1. Hall Effect in Semiconductor
2. Two Probe Method for Resistivity Measurement.
3. Forbe’s Method
4. Fourier Filtering
5. Elastics Constants – Elliptical and Hyperbolic Fringes
6. Hysteresis (B – H Curve)
7. Helmholtz Galvanometer
8. Conductivity of Thin Film – Four Probe Method
9. Curie Temperature of Magnetic Materials
10. Dielectric Constant and Curie Temperature of Ferroelectric Ceramics

References

1. R. A. Dunlop, “Experimental Physics”, Oxford University Press.
2. A. C. Melissinos, “Experiments in Modern Physics”, Academic Press.

PH 501: Atomic and Molecular Physics (3-1-0: 4)

One Electron Atom and Interaction of Radiation with Matter

Quantum states, atomic orbital, parity of the wave function, angular and radial distribution functions, time dependent perturbation, interaction of an atom with electromagnetic wave. **[6L+2T]**

Fine and Hyperfine Structure

Solution of Dirac equation in a central field, relativistic correction to the energy of one electron atom, Fine structure of spectral lines, selection rules, Lamb shift. Stark, Zeeman and Paschen-Back effect, Hyperfine interaction and isotope shift, hyperfine splitting of spectral lines, selection rules. **[9L+3T]**

Many Electron Atom

Independent particle model, central field approximation, L-S and j-j coupling, energy levels and spectra, spectroscopic terms, Hunds rule, Lande interval rule, transition probabilities and intensity of spectral lines, line broadening mechanisms, alkali spectra. **[6L+2T]**

Molecular Electronic States

Concept of molecular potential, Born-Oppenheimer approximation, electronic states of diatomic molecules, electronic angular momenta, the linear combination of atomic orbitals (LCAO) approach, states for hydrogen molecular ion, Symmetries of electronic wavefunctions, shapes of molecular orbital, π and σ bond, term symbol for simple molecules. **[9L+3T]**

Rotation and Vibration of Molecules

Molecular rotation, molecular vibrations, Morse potential, pure vibrational transitions, pure rotational transitions, vibration- rotation transitions, electronic transitions, Franck-Condon principle, rotational structure of electronic transitions, Fortrat diagram, dissociation energy of molecules, FTIR and Raman spectroscopy. **[6L+2T]**

Text Books & References

1. H. E. White, “Introduction to Atomic Spectra”, Tata McGraw Hill.
2. C. B. Banwell, “Fundamentals of Molecular Spectroscopy”, Tata McGraw Hill.
3. B. H. Bransden and C. J. Joachain, “Physics of Atoms and Molecules”, Pearson Education.
4. M. Born, “Atomic Physics”,New York Dover Publications.
5. H. Herzberg, “Spectra of Diatomic Molecules”, Springer.
6. C. N. Banwell & E. M. McCash, “Fundamentals of Molecular Spectroscopy”,New Delhi MGH.

PH 503: Condensed Matter Physics (3-1-0:4)

Crystal Structure
Space lattice and unit cells, crystal system, symmetry operation, point groups and space groups, plane lattices and their symmetries. Miller Indices, representation of directions and planes, packing fractions, simple crystal structures. X-ray diffraction by crystals. Laue theory, interpretation of Laue equations, Bragg's law, reciprocal lattice. Ewald construction, atomic scattering factor. Brief discussion on neutron and electron diffraction. **[6L+3T]**

Phonon and Lattice Vibrations
Vibrations of one-dimensional monatomic and diatomic lattices. Infrared absorption in ionic crystals (one-dimensional model). Normal modes and phonons. Frequency distribution function. Review of Debye's theory of lattice specific heat. Anharmonic effects. **[6L+2T]**

Free Electron Theory and Energy Bands
Energy level in one dimension, free electron gas in three dimension, heat capacity of the electron gas, Drude model, electron transport, Hall effect, thermal conductivity of metals. Nearly free electron model, Bloch function, Kronig- Penney Model, wave equation of electron in a periodic potential, number of orbitals in a band. **[6L+2T]**

Semiconductor
Formation of bands, band gap, intrinsic carrier concentration, concept of a hole, impurity conductivity, Fermi level, direct and indirect band gap, p-n junction, drift current, diffusion current. **[6L+2T]**

Magnetic Properties of Solids
Diamagnetism, Langevin equation. Quantum theory of paramagnetism. Curie law. Hund's rules. Paramagnetism in rare earth and iron group ions. Ferromagnetism. Curie-Weiss law. Heisenberg exchange interaction. Mean field theory. Nuclear magnetic resonance. **[6L+2T]**

Superconductivity
Meissner effect, Flux quantization, London's equation, Type I and Type II Superconductors, Outline of BCS theory, Josephson Junction, SQUIDS. **[6L+1T]**

Textbooks and References

1. N. W. Ashcroft and N. Mermin, "Solid State Physics", Brooks.
2. C. Kittel, "Introduction to Solid State Physics", Wiley.
3. A. J. Dekkar, "Solid State Physics" Macmillan & Co Ltd.
4. J. R. Christman, "Fundamentals of Solid State Physics", John Wiley & Sons.
5. B. Di Bartolo and B. College, "Crystal Symmetry, Lattice Vibrations and Optical Spectroscopy of Solids: A Group Theoretical Approach", World Scientific.
6. C. A. Wert and R. M. Thomson, "Physics of Solids", McGraw-Hill Book Company.
7. J. P. Srivastava, "Elements of Solid State Physics", Prentice Hall India.

PH 505: Nuclear & Particle Physics (4-0-0: 4)

Nuclear Properties

The nuclear radius, mass and abundance of nuclides, nuclear binding energy, nuclear angular momentum and parity, nuclear electromagnetic moments, nuclear excited states. **[6L]**

The Force between Nucleons and Nuclear Models

Deuteron, proton-proton and neutron-neutron interaction, properties of the nuclear force, exchange force model, shell model, even–Z, even-N nuclei and collective structure, realistic nuclear models. **[10L]**

Radioactive Decay

Radioactive decay law, production and decay of radioactivity, growth of daughter activities, types of decays, natural radioactivity, alpha decay, beta decay, gamma decay. **[9L]**

Nuclear Reactions

Types of reaction and conservation laws, isospin, nuclear fission, nuclear fusion. **[7L]**

Detectors and Accelerators

Interaction of radiation with matter, gas filled counters, GM counter, scintillation detectors, semiconductor detectors, electrostatics accelerators, cyclotron accelerators, synchrotrons, linear accelerators, colliding-beam accelerators. **[4L]**

Particle Physics

Yukawa's hypothesis, properties of mesons, symmetries and conservation laws, Standard model, particle classification, quark model, colored quarks, gluons and strong interaction. **[12L]**

Text Books and References

1. K. Heyde, "Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach", 3rd edition, CRC Press, 2004.
2. J. L. Basdevant, J. Rich and M. Spiro "Fundamentals in Nuclear Physics", 1st edition, Springer, 2005.
3. W. Greiner and J. A. Maruhn "Nuclear Models", Springer, 2009
4. S. Tavernier, "Experimental Techniques in Nuclear and Particle Physics", Springer, 2014
5. M. Thomson, "Modern Particle Physics", Cambridge University Press, 2016.
6. FI. Stancu, "Group Theory in Subnuclear Physics", 1st edition, Oxford Science Publications, 1996.

PH 581: Optics Laboratory (0-0-6: 3)

1. **Faraday Rotation**: Verdet constants of glass and water from measurements of the rotation angle as a function of the magnetic field strength.

2. **Fibre Optics**: Study the basic structure and types of the optical fiber, measure the numerical aperture and output power.

3. **Michelson Interferometer**: Measurement of Wavelength and Refractive index.

4. **Kerr Effect:** Quadratic electro-optic effect.

5. **Zeeman Effect**: Study the splitting of degenerate energy levels in mercury under application of a strong magnetic field.

6. **Fabry-Perot Etalon**: Very precise measurement of the wavelength of a spectral line.

7. **Muon Lifetime**: Measure speed of cosmic-ray muons and infer relativistic effects; measure the lifetime of muons decaying at rest.

8. **Nuclear Magnetic Resonance**: Measure the proton magnetic moment, and verify that the spin t/z proton is not a Dirac particle.

9. **The Franck-Hertz Experiment**: Demonstrated the existence of excited states in Mercury/ Neon atoms, helping to confirm the quantum theory which predicted that electrons occupied only discrete, quantized energy states.

10. **Magnetic Susceptibility-Gouy's Method**: Determination of magnetic susceptibility of solid samples.

11. **Magnetic Torque**: To make quantitative measurements involving electromagnetism, torque and simple harmonic motion and also to study, quantitatively, the phenomenon of precession.

Text Books & References

1. N. Menn, "Practical Optics", Elsevier Academic Press.
2. H. S. Hans, "Nuclear Physics: Experimental and Theoretical", New Age International.
3. R. S. Sirohi, "A Course of Experiments with He-Ne Laser", New Age International.

Elective-I

PH 521: Light-Matter Interaction (3-0-0: 3)

Classical and Semi-classical Treatment of Light-Matter Interaction
Lorentz oscillator, Drude model, susceptibility and complex refractive index, Kramer Kronig relation, Sellmeier equations, anisotropic media, polarization optics, electronic transitions in atoms, two-level interactions. Relaxation oscillators in Lasers, Rabi-oscillations, density matrix formulation, energy and phase relaxation. **[9L]**

Nonlinear Optics
Nonlinear perturbation theory and coupled mode equations, anharmonic classical oscillator model, second order & third order effects, phase-matching mechanisms, vibrational transitions in molecules and Raman nonlinearity, Kerr nonlinearity. **[9L]**

Ultrafast Optics
Definition of ultrashort pulses, propagation of ultrashort optical pulses through dispersive optical elements, femto-second lasers and their applications, characterization of ultrashort pulses, temporal-lens, introduction to coherent control. **[9L]**

Nano-photonics and Metamaterials
Metal optics, propagating and localized surface plasmons, effective medium theories, transformation optics, recent experiments in linear and nonlinear metamaterials. **[9L]**

Text Books and References

1. C. C. Tannoudji, J. D. Roc, and G. Grynberg, “Atom-Photon Interactions: Basic Processes and Applications”, Wiley-VCH.
2. P. E. Powers, “Fundamentals of Nonlinear Optics”, CRC Press.
3. A. Weiner, “Ultrafast Optics”, John Wiley & Sons.
4. B. E. A. Saleh and M. C. Teich, “Fundamentals of Photonics”, John Wiley & Sons.
5. R. W. Boyd, “Nonlinear Optics", Academic Press.
6. P. Meystre and M. Sargent, “Elements of Quantum Optics”, Springer.

PH 523: Spintronics (3-0-0: 3)

History of Spin
Spin, the Bohr planetary model and space quantization, the birth of spin, the Stern-Gerlach Experiment. **[3L]**

Quantum Mechanics of Spin
Pauli spin matrices, the Pauli equation and spinors, more on the Pauli equation, extending the Pauli equation, the Dirac equation. **[2L]**

Spin Orbit Interaction
Spin orbit interaction in solid, Rashba interaction, Dresselhaus interaction. **[3L]**

Exchange Interaction
Direct exchange, indirect exchange, superexchange interaction, double exchange, RKKY exchange interaction. **[2L]**

Spin Relaxation
Elliott-Yafet mechanism, D'yakonov Perel' mechanism, Bir-Aronov-Pikus mechanism, hyperfine interaction with nuclear spin. **[4L]**

Spin Dependent Electron Transport
Basic transport in continuous thin film, Datta -Das transistor, elastic scattering, inelastic scattering, basic transport in discontinuous film, thermoionic emission, tunneling, Andreev reflection theory at ferromagnetic/semiconductor interface. **[8L]**

Spin Transfer Torque and its Magnetic Dynamics
Spin injection phenomena, dynamics of domain wall, magnetoresistance, giant magnetoresistance (GMR), tunnel magnetoresistance (TMR). **[7L]**

Application to Spintronics
Spin photoelectronic devices, magnetic tunneling devices, spin qubits, Quantum spin hall effect, band inversion, strained semiconductor, HgTe-CdTe quantum well. **[7L]**

Text Books and References

1. S. Bandyopadhyay and M. Cahay, "Introduction to Spintronics", CRC Press.
2. Y. Xu, D. D. Awschalom and J. Nitta, "Handbook of Spintronics", Springer.
3. T. Dieti, D. D. Awschalom, M. Kaminska and H. Ohno, "Spintronics", Academic Press.
4. T. Shinjo, "Nanomagnetism and Spintronics", Elsevier.
5. C. Felser and G. H. Fecher, "Spintronics", Springer.
6. M. Johnson, "Magnetoelectronics", Academic Press.

PH 525: Biological Physics (3-0-0: 3)

Physical Biology
Physical biology of the cell, the stuff of life: four great classes of macromolecules, different physical models in biology, quantitative models and the power of idealization: springiness of stuff, the unifying ideas of biology, mathematical toolkit, biology by the numbers, cells and their contents: an ode to E. Coli, cells and structures within them. **[7L]**

Thermodynamics of Living Systems
Energy and the life of cells, equilibrium models: proteins in equilibrium, cells in equilibrium, minimizing the potential energy, the mathematics of superlatives, Hooke's law: actin to lipids, entropy and hydrophobicity, gibbs and the calculus of equilibrium, an ode to ΔG, the statistical mechanics of gene expression, Boltzmann distribution & entropy, osmotic pressure & forces: interstrand interactions of DNA, law of mass action, applications of the calculus of equilibrium, random walks and structure of macromolecules, DNA as a random chain, single molecule mechanics. **[8L]**

Dynamics of Biomolecules
The mathematics of water: water as a continuum, F=ma for fluids, the Newtonian fluid and the Navier–Stokes equations, fluid dynamics of blood, life at low eynold's number, diffusion in the cell, diffusive dynamics: Fick's law, the Smoluchowski equation, the Einstein relation, biological statistical dynamics, molecular motors, translational motors: myosin, biased random walk. **[8L]**

Biological Electricity & Quantum Biology
The charge on DNA and proteins, electrostatics for salty solutions: the charged life of a protein, Poisson–Boltzmann equation, viruses as charged spheres, the role of electricity in cells, the charge state of the cell, the action potential, quantum mechanics for biology: photosynthesis, the particle in a box model, bioenergetics of photosynthesis, vision: microbial phototaxis and manipulating cells with light, relationship between eye geometry and resolution, photoreceptor cell. **[8L]**

Physical Methods in Biology and Medicine
X-ray crystallography, fluorescence spectroscopy, electron microscopy, nuclear magnetic resonance, atomic force microscopy, tomography, sonograms, radiation therapy, pacemakers. **[5L]**

Text Books & References

1. P. Nelson, "Biological Physics: Energy, Information, Life", W. H. Freeman.
2. R. Cotterill, "Biophysics: An Introduction", Willey.
3. R. Glaser, "Biophysics", Springer.
4. R. Nossal and H. Lecar, "Molecular & Cell Biophysics", Addison-Wesley.
5. C. R. Cantor and P. R. Schimmel, "Biophysical Chemistry: vol. I, II & III", W. H. Freeman.

PH 527: Phase Transitions and Critical Phenomena (3-0-0: 3)

Introduction

Order of Phase transition, Ehrenfest criterion, examples of First and second order phase transition, critical points and exponents, inequalities. **[4L]**

Models

The spin - 1/2 Ising model, spin - 1 Ising model, q state Potts model, X-Y model, Heisenberg model. **[5L]**

Mean field theories

Introduction to mean field theory, Weiss mean field theory, Bragg-Williams mean field theory, Transfer matrix formalism, correlation functions, Landau theory of phase transition, scaling laws, upper critical dimension. **[10L]**

Series expansions

Series expansion, applications to Ising model. **[4L]**

Monte Carlo simulations

Importance sampling, Metropolis algorithm, error analysis. **[5L]**

The renormalization group

Renormalization Group transformation, RG flow equations, scaling and critical exponents, applications to 1D Ising model. **[8L]**

Text Books & References

1. H. E. Stanley, "Introduction to Phase Transitions and Critical Phenomena", Oxford University Press.
2. J. M. Yeomans, "Statistical Mechanics of Phase Transitions", Oxford University Press.
3. D. Chandler, "Introduction to Modern Statistical Mechanics", Oxford University Press.
4. R. K. Pathria and P. Beale, "Statistical Mechanics", Academic Press.
5. M. Plischke and B. Bergersen, "Equilibrium Statistical Physics", Wspc.

PH 529: Non-Equilibrium Statistical Mechanics (3-0-0: 3)

Introduction
Correlation functions, Response functions, the harmonic oscillator, dissipation, elastic waves and phonons. **[6L]**

Diffusion
Fick's law, Brownian motion, Langevin theory, Fokker-Planck and Smoluchowski equations. **[10L]**

Fluctuation dissipation
Fluctuation dissipation theorem, examples of magnetic systems in presence of a magnetic field. Inelastic scattering, Onsager relations, Neutron scattering, scattering of charged particles and photons. **[10L]**

Linear response
Linear response theory, current-current correlator, Kubo formula, Spin Dynamics, Ferro and Antiferromagnets, Vortices in XY model, Crystal growth, Grain boundaries, dislocation and melting. **[10L]**

Text Books & References

1. R. K. Pathria and P. D. Beale, "Statistical Mechanics", Academic Press.
2. P. V. Panat, "Thermodynamics and Statistical mechanics", Narosa.
3. V. Balakrishnan, "Elements of Nonequilibrium Mechanics", Ane Books Pvt. Ltd.
4. L. E. Reichl, "A Modern Course in Statistical Physics", Wiley - VCH.
4. Chaikin & Lubensky, "Principles of Condensed Matter Physics", Cambridge University Press.

National Institute of Technology Meghalaya An Institute of National Importance

CURRICULUM

Programme	**Master of Science in Physics**	Year of Regulation				2019			
Department	**Physics**	Semester				III			
Course Code	Course Name	Credit Structure				Marks Distribution			
		L	T	P	C	INT	MID	END	Total
PH 531	**Nanoelectronics**	**3**	**0**	**0**	**3**	**50**	**50**	**100**	**200**

Course Objectives		Course Outcomes		
Course Objectives	To introduce the (i) electron dynamics in nanoscale devices and (ii) concepts of single-electron tunnelling and its application.	Course Outcomes	CO1	Understand the nanoelectronics concepts using quantum mechanics
			CO2	Analyse the electron transport phenomena at the nanoscale level
			CO3	Understand the working mechanism of single-electron tunneling
			CO4	Acquire the ability to degign the circuit and simulation in nanoelectronics

SYLLABUS

No	Content	Hours	COs
1	**Quantum Theory for Nanoelectronics** Review of electronic technology, mathematics for nanoscale systems, free electrons in quantum mechanics, current and tunnel current, energy in circuit theory, two-capacitor circuit.	6	CO1
2	**Electron Dynamics in Nanoscale Devices** Introduction to electron transport, equilibrium Green's function in electron transport, electric current under linear response, General Kubo conductivity, non-equilibrium electron transport, electron propagation- physics of Green's function, device current formalism.	10	CO2
3	**Single Electron Tunneling** Tunneling capacitor, Coulomb blockade, quantum dot circuit, double junction system, Single-Electron Transistor (SET), impulse circuit model for SET: Zero and non zero tunneling time SET circuit examples.	10	CO3
4	**Circuit Design and Simulation** Challenges of circuit design, signal amplification, biasing and coupling, SPICE model, the introduction of fuzzy logic and neural networks for circuit design.	10	CO4
	Total Hours	36	

Essential Readings

1. J. Hoekstra, "Introduction to Nanoelectronic Single-Electron Circuit Design", Pan Stanford Publishing Pte. Ltd.
2. S. G. Tan and Mansoor B. A. Jalil, "Introduction to the physics of nanoelectronics", Woodhead Publishing Limited.
3. G. W. Hanson, "Fundamentals of Nanoelectronics", Pearson India.

Supplementary Readings

1. Joachim Knoch, "Nanoelectronics:Device Physics, Fabrication, Simulation", De Gruyter Oldenbourg.

Elective – II & III

PH 522: Measurement Techniques and Cryogenics (3-0-0:3)

Kinetic Theory of Gases: Behaviour of gases, pressure of gases, Maxwell's law, gas transport phenomenon; viscous, molecular and transition flow regimes. **[4L]**

Vacuum Generation: Measurement of pressure, residual gas analyses; production of vacuum - mechanical pumps, rotary vane pumps, diffusion pump, cryopumps, turbo-molecular pumps, getter and ion pumps, choice of pumping process. **[8L]**

Vacuum Measurement: Fundamentals of low-pressure measurement, vacuum gauges- McLeod gauge, pirani gauge, penning gauge, thermal conductivity gauges - cold cathode and hot cathode ionisation gauges, materials in vacuum; high vacuum, and ultra high vacuum systems, leak detection. **[10L]**

Noise Control: Basics of sound and noise, noise sources; types and measurement, noise screening, principles of noise control, silencers and their types. **[4L]**

Cryogenics: Properties of engineering materials at low temperature, cryogenic fluids and their physical properties, super-fluidity, refrigeration; pomeranchuk cooling, thermoelectric coolers, closed cycle refrigeration, single and double cycle He^3 refrigerator, He^4 refrigerator, cryostat design; cryogenic level sensors, handling of cryogenic liquids; cryogenic fluid storage, insulations, cryogenic fluid transfer systems, cryogenic thermometry. **[10L]**

Textbooks and References

1. D. M. Hoffman, B. Singh and J. H. Thomas, "Handbook of Vacuum Science and Technology", Academic Press Limited.
2. J. M. Lafferty, "Foundations of Vacuum Science and Technology", Wiley-Blackwell.
3. V. V. Kostionk, "A Text Book Of Cryogenics", Discovery Publishing House.
4. T. M. Flynn, "Cryogenic Engineering", Marcel Dekker.
5. P. V. E McClintock, D. J. Meredith and J. K. Wigmore, "Low-temperature Physics: An Introduction for Scientists and Engineers", Springer Science.

PH 524: Numerical Methods and Computational Physics (3-0-0: 3)

Errors
The importance of estimating errors, systematic and random errors, absolute and relative errors, general formula for errors, error propagation, method of least squares, floating point errors, floating point complications, overflow and underflow. **[6L]**

Matrices and Linear Algebraic Equations
Addition, subtraction and multiplication of matrices, transpose of a matrix, Gauss-Jordan elimination, Gauss-Seidel elimination, LU Decomposition, applications, eigen value problem. **[5L]**

Root Finding and Nonlinear Sets of Equations
Bisection method, Newton–Raphson method, Secant method, applications. **[4L]**

Interpolation
Lagrange polynomials. **[2L]**

Modeling of Data
Least square fitting of functions and its applications. **[4L]**

Numerical differentiation
Forward, backward and centred difference formula. **[4L]**

Solution of ordinary differential equations
Euler's method, second and fourth order Runge-Kutta methods, finite difference method, boundary value problems. **[5L]**

Numerical integration
Trapezoidal, Simpson and Gaussian Quadratures rules, applications. **[3L]**

Monte-Carlo methods
Random number generation, checking the randomness of a sequence, Monte-Carlo integration. **[3L]**

Text Books and References

1. V. Rajaraman, "Computer Oriented Numerical Methods", PHI Learning Publishers.
2. R. L. Burden and J. D. Faires, "Numerical Analysis", Brooks Cole Publishing.
3. K. P. N. Murthy, "Monte-Carlo Methods in Statistical Physics", University Press.
4. H. T. Davis and K. T. Thomson, "Linear Algebra and Linear Operators in Engineering with Applications In Mathematica", Academic Press.
5. R. L. Burden and J. Douglas Faires, "Numerical Analysis", Thomson Learning

PH 528: Computational Lab (0-0-6: 3)

1. Uniform random number generation – Park and Miller method
2. Gaussian random number generation – Box and Muller method
3. Matrix addition, subtraction and multiplication
4. Transpose of a matrix
5. Roots of algebraic equations – Newton–Raphson method
6. Least-squares curve fitting – Straight-line fit and Exponential fit
7. Solution of simultaneous linear algebraic equations – Gauss elimination method
8. Solution of simultaneous linear algebraic equations – Gauss-Seidel method
9. Interpolation – Lagrange method
10. Numerical differentiation
11. Numerical Integration – Trapezoidal, Simpson and Gaussian Quadratures rules
12. Solution of ordinary differential equations – Runge-Kutta 2^{nd} /4^{th} order method
13. Monte Carlo simulation of Ising model

Text Books and References

1. G. L. Squires, "Practical Physics", Cambridge University Press.
2. V. Rajaraman, "Computer Oriented Numerical Methods", PHI Learning Publishers.
3. H. M. Antia, "Numerical Methods for Scientists and Engineers", Hindustan Book Agency.
4. K. P. N. Murthy, "Monte-Carlo Methods in Statistical Physics", University Press.

Elective –IV

PH 542: Science and Technology of Thin Films (3-0-0: 3)

Thermodynamics of Evaporation
Kinetic theory of gases, effusion, Hertz Knudsen equation; mass evaporation rate; Knudsen cell, directional distribution of evaporating species, evaporation of elements, compounds, alloys, Raoult's law. **[8L]**

Physical Vapor Deposition
Thermal, e-beam, pulsed laser and ion beam evaporation, glow discharge and plasma, sputtering - mechanisms and yield, dc and rf sputtering, bias sputtering, magnetically enhanced sputtering systems, reactive sputtering. **[8L]**

Chemical Vapor Deposition
Gas flow system, reaction chemistry and thermodynamics of CVD; thermal CVD, laser & plasma enhanced CVD. Chemical techniques - spray pyrolysis, electrodeposition, sol-gel and LB techniques. **[8L]**

Nucleation & Growth
Elastic scattering, sticking coefficient, mechanisim of thin film formation, 2D & 3D growth, rate of nucleation. Epitaxy - homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors, scope of devices and applications. **[8L]**

Substrate Preparation and Thickness Measurement
Contamination and cleaning process, chemical etching, physical etching, and etching induced damage. Thickness measurement by Talystep, quartz crystal microbalance, and optical methods. **[4L]**

Text Books and References

1. K. S. S. Harsha, "Principles of Physical Vapor Deposition of Thin Films", Elsevier.
2. D. L. Smith, "Thin- Film Deposition: Principles and Practices", McGraw-Hill Education.
3. M. L. Hitchman and K. F. Jensen, "Chemical Vapor Deposition: Principles and Applications", Academic Press.
4. D. Kashchiev, "Nucleation: Basic Theory with Applications", Butterworth-Heinemann.
5. H. H. Gatzen, V. Saile and J. Leuthold, "Micro and Nano Fabrication: Tools and Processes", Springer.

PH 544: Nanoscience and Technology (3-0-0: 3)

Background to Nanotechnology
Scientific revolution, physics of low-dimensional materials, atomic structures, 1D, 2D and 3D confinement, density of states, excitons, emergence of nanotechnology, challenges in nanotechnology. Carbon age: new form of carbon (from graphene sheet to CNT). Risks and benefits of nanomaterials. **[6L]**

Different Classes of Nanomaterials
Carbon nanotubes (CNT), metals (Au, Ag), metal oxides (TiO_2, CeO_2, ZnO), semiconductors (Si, Ge, CdS, ZnSe), ceramics and composites, dilute magnetic semiconductor, size dependent properties, mechanical, physical and chemical properties. **[6L]**

Nanostructure Fabrication
Top-down approach: Lithography. Bottom-up approach: PVD & CVD. **[8L]**

Nanoelectronics
Tunnel junction, Coulomb blockade and single electron transistor: operating principle, technology and application, carbon based devices. **[8L]**

Nanobiotechnology
Protein-based nanostructures, engineered nanopores, DNA-based nanostructures, Nanoparticle–biomaterial hybrid systems for bioelectronic devices, DNA-gold nanoparticle conjugates. **[8L]**

Text Books and References

2. M. Kuno, “Introductory Nanoscience: Physical and Chemical Concepts”, Garland Science.
3. H. H. Gatzen, V. Saile and J. Leuthold, “Micro and Nano Fabrication: Tools and Processes”, Springer.
4. G. W. Hanson, “Fundamentals of Nanoelectronics”, Pearson.
5. C. M. Niemeyer and C. A. Mirkin, “Nanobiotechnology Concepts, Applications and Perspectives”, Wiley-VCH.

PH 546: Physics of Liquid Crystals (3-0-0: 3)

Classification of Liquid Crystals
Symmetry structure and classification of liquid crystal, polymorphism in thermotropics, reentrant phenomenon in liquid crystals, blue phases, polymer liquid crystals, distribution functions and other parameters, macroscopic and microscopic order parameters, measurement of order parameters, magnetic resonance, electron spin resonance, Raman scattering and X-ray diffraction. **[6L]**

Theories of Liquid Crystalline Phase Transition
Nature of phase transitions and critical phenomenon in liquid crystals, hard particle, Maier-Saupe and van der Waals theories for nematic–isotropic and nematic-smectic A transitions Landau theory, essential ingredients applications to nematic-isotropic and nematic-smectic A transitions and transitions involving smectic phases. **[6L]**

Continuum Theory
Curvature elasticity in nematic smectic A phases, distortions due to magnetic and electric fields, magnetic coherence length, Freedeicksz transitions, field induced cholesteric nematic transition. **[6L]**

Dynamical Properties of Nematic
The equations of nemato-dynamics, laminar flow, molecular motions, optical properties of cholesterics, optical properties of ideal helices, agent influencing the pitch, liquid crystal display. **[6L]**

Ferroelectric Liquid Crystals
The properties of smectic C continuum description smectic C- smectic A transition applications. Discotic liquid crystals: symmetry and structure, mean field description of discotic liquid crystals, continuum description, lyotropic liquid crystals and biological membrane. **[6L]**

Applications of Liquid Crystals
Liquid crystal applications in LCDs, switchable windows, demonstrations, non-display applications, thermochromics and Kevlar. **[6L]**

Text Books and References

1. S. Chandrasekhar, "Liquid Crystals", Cambridge University Press.
2. G. Vertogen and W. H. de Jeu, "Thermotropic Liquid Crystals: Fundamentals", Springer.
3. P. G. de Gennes and J. Prost, "The Physics of Liquid Crystals", Clarendon Press.
4. P. J. Collings and M. Hird, "Introduction to Liquid Crystals: Physics and Chemistry", Taylor and Francis.
5. D. Yang and S. Wu, "Fundamentals of Liquid Crystal Devices", Wiley.
6. S. T. Lagerwall, "Ferroelectric and Antiferroelectric Liquid Crystals", Wiley-VCH.

PH552: Quantum Information and Computation (3-0-0:3)

Framework of Quantum Mechanics
The Stern Gerlach experiment, Quantum State and the vector representation, fundamental postulates, operators, basic transformation, multipartite system, Tensor product and entangled state, Cbits and Qbits. **[6L]**

Qubits
The Bloch sphere: point on the sphere, orthogonal qubits, point inside the sphere. Qubit projections, Bloch sphere rotations. Single qubit logic gates, multiple qubits, two qubit system and logic gates. The Bell state and EPR paradox. Testing Bell's inequality. Three qubit system, quantum adder. Quantum Gate: controlled-U gate, controlled-V gate and Toffolic gate. **[10L]**

Qubits Measurements
Implicit measurement and deferred measurement. Qubits error: Qubit-flips and phase-flips. Qubit error correction. Parallelism: computing and superposition, Deutsch's algorithm, Grover's algorithm, and Shor's algorithm, Entanglement and its measures, No-Cloning theorem, dense coding and quantum teleportation.
[10L]

Quantum Computing
DiVincenzo criteria and physical realizations. NMR quantum computer, single-spin and multi-spin Hamiltonian, Implementation of gates and algorithms, Qubit tomography. Quantum computing with trapped ions and neutral atoms. **[10L]**

Text Books and References

1. O. A. Cross, "Quantum Mechanics and Quantum Computing Notes", 1st edition, Create Space Independent Publishing Platform, 2017.
2. D. McMahon, "Quantum Computing Explained", Wiley, 2016.
3. M. Nakahara and T. Ohmi, "Quantum Computing: From Linear Algebra to Physical Realizations", 1st edition, CRC Press, 2008.
4. Vathsan, Radhika, "Introduction to Quantum Physics and Information Processing", 1st edition, CRC Press, 2015.
5. N. David Mermin, "Quantum Computer Science: An Introduction", Cambridge University Press, 2007.
6. M. A. Nielsen and I. L. Chuang, "Quantum Computation and Quantum Information", 10th edition, Cambridge University Press, 2010.