|  |
| --- |
| Semester I |
| Course code | Course Name | L-T-P | C | Prerequisites |
| PH 401 | Mathematical Physics-I | 3-1-0 | 4 | None |
| PH403 | 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 |  |

# CourseDetail

|  |  |
| --- | --- |
| ProgramName | MSc Physics |
| Duration | 2Year(fulltime) |
| Eligibility | 1. B.Sc.(PassorHons.)Physics/AppliedPhysicswithMathematicsas one of the Ancillary subject from UGC recognised Universities
2. 60%marks(General/OBC),55%marksincaseofSC/STandPwD Category
 |
| Admission | CentralizedCounsellingthroughCCMNandInstituteEntranceTestforremainingvacantseats |
| Intake | 16 |

**EvaluationPlan**

TheoryCourses

|  |  |  |
| --- | --- | --- |
| Assessmenttask | Typeofassessment | Weightageoftotalassessmentin% |
| Assignment-I | Formative | 10marks(5%) |
| ClassTest–I(1-hourtest) | Summative | 15marks(7.5%) |
| MidTerm(2-hour exam) | Summative | 50marks(25%) |
| Assignment-II | Formative | 10marks(5%) |
| ClassTest–II(1-hourtest) | Summative | 15marks(7.5%) |
| EndTerm(3-hourexam) | Summative | 100marks(50%) |

LaboratoryCourses

|  |  |  |
| --- | --- | --- |
| Assessmenttask | Typeofassessment | Weightageoftotalassessmentin% |
| VivaVoce-I |  | 20marks(20%) |
| Lab performance | Formative | 30marks(30%) |
| VivaVoce-2 |  | 20marks(20%) |
| Lab copy |  | 30marks(30%) |

Dissertation

|  |  |
| --- | --- |
| Assessmenttask | Weightageoftotalassessmentin% |
| ReportPreparation&Work performance  | 30marks(30%)  |
| SeminarPresentation | 20marks(20%) |
| Viva Voce | 20marks(20%) |
| FinalReport | 30marks(30%) |

TotalNumberofCredit:80 Core Course: 46

Practical:11

Project:10

DepartmentalElective:12

OtherCourse:01

# PH401:MathematicalPhysics-I(3-1-0:4)

### TransformationandVectorCalculus

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

### VectorSpaces

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**]

### OrdinaryDifferentialEquations

Introduction, First-Order Equations, ODEs with Constant Coefficients, Second-Order Linear ODEs, SeriesSolutions-Frobenius’ method. **[6L+2T]**

### SpecialFunctions

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

### ProbabilityandStatistics

Probability: Definitions, Simple properties, Random variables, Binomial distribution, Poisson distribution,Normaldistribution,centrallimittheorem. **[6L+2T]**

### Textbooksand References

1. Arfken, Weber and Harris, “Mathematical Methods for Physicists”, 7th edition, Academic Press,2012.
2. Riley,HobsonandBence,“MathematicalMethodsforPhysicsandEngineering’’,3rdedition, 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,“MathematicalPhysics-TheBasics”,1stedition,UniversitiesPress,2002.
5. V.Balakrishnan,“MathematicalPhysicswithApplications”,AneBooks,2017.
6. R. Courant and D. Hilbert, “Methods of Mathematical Physics, Vol. 1”,1st edition, Wiley VCH,1989.
7. P.DenneryandA.Krzywicki,“MathematicsforPhysicists”,DoverPublications,2012.
8. R.BealsandR.Wong,“SpecialFunctions:AGraduateText”,CambridgeUniversityPress, 2010.
9. E.Kreyszig,“AdvancedEngineeringMathematics”, 10thedition,JohnWiley&SonsInc,2015.

# PH403:QuantumMechanics-I(3-1-0:4)

### QuantumTheory

Empiricalbasis,wave-particleduality,particleaspectofradiation,waveaspectofmatter. **[2L]**

### StructureofQuantumMechanics

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]**

### QuantumDynamics

TimeevolutionandtheSchrödingerequation,Schrodinger,HeisenbergandInteractionrepresentation, position and momentum representation, Expectation values, time-independent Schrödinger equation.

## [6L+2T]

### One-dimensionalSchrödingerEquation

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 inauniformmagneticfield,coherent states. **[6L+2T]**

### WaveMechanicsinthreedimensions

Separation of variables in spherical polar coordinates, orbital angular momentum, parity, spherical harmonics,freeparticleinspherical polarcoordinates,sphericalpotential,hydrogenatom,degeneracy and accidental degeneracy. **[6L+2T]**

### AngularMomentumandIdenticalParticles

Rotation operators, angular momentum algebra, eigenvalues of J2 and Jz, spinors and Pauli matrices, addition of angular momenta. Identical particles, indistinguishability, symmetric and antisymmetric wavefunctions,incorporationofspin,Slaterdeterminants,Pauliexclusionprinciple. **[9L+3T]**

### Textbooksand References

1. M.Beck,“QuantumMechanics:TheoryandExperiment”,1stedition,OxfordUniversityPress, USA, 2012.
2. N.Zettili,“QuantumMechanicsConceptsandApplication”,2ndedition,WileyIndiaPvt.Ltd, 2016.
3. JohnS.Townsend,“AModernApproachtoQuantumMechanics”,2ndedition,UniversityScience Books, California, 2012.
4. C. C. Tannoudji, B. Diu, and F. Laloe, Quantum Mechanics, Volume 1,1st edition, Wiley VCH,1997.
5. E.Merzbacher,“QuantumMechanics”,3rdedition,JohnWiley&Sons,2011.
6. W.Greiner,“QuantumMechanicsAnIntroduction”,3rdedition,Springer,1994.

# PH405:ClassicalMechanics(3-1-0:4)

### LagrangianandHamiltonianFormulationsofMechanics

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]**

### RigidBody Dynamics

Eulerequations,heavysymmetricaltop,precession,nutation. **[3L+1T]**

### Two-BodyCentralForceProblem

Equation of motion and first integrals, classification of orbits, Kepler problem, scattering in centralforce field, Laboratory and centre of mass frames, Scattering cross section, Rutherford scattering.

## [9L+3T]

### SmallOscillations

Linearizationofequationsofmotion,normalmodesandnormalcoordinates,forcedoscillations.

## [3L+1T]

### CanonicalTransformations

Poissonbrackets,HamiltonJacobitheory,Action-anglevariables. **[3L+1T]**

### SpecialTheoryofRelativity

Postulates of special theory of relativity, Lorentz transformation, Length contraction, Time dilation, Simultaneity,Relativistickinematicsanddynamics,MinkowskiSpace. **[9L+3T]**

### Textbooksand References:

1. H.Goldstein,“ClassicalMechanics”,3rdedition,PearsonEducationIndia,2011.
2. L.D.LandauandE.M.Lifshitz,“Mechanics”,3rdedition,Butterworth-Heinemann,1982.
3. I.C.PercivalandD.Richards,“IntroductiontoDynamics”,CambridgeUniversityPress,1982.
4. J.V.JoseandE.J.Saletan,“ClassicalDynamics:AContemporaryApproach”,Cambridge University Press, 1998.
5. J.R.Taylor,“ClassicalMechanics”,CaliforniaUniversityScienceBooks,2004.
6. R.Resnick,”IntroductiontoSpecialRelativity”,1stedition,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.

# PH407:ElectromagneticTheory(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,lineardielectrics,boundaryvalueproblems,energyindielectrics. **[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

Electromotiveforce,Motionalemf,InducedElectricField, Faraday’sLaw,Inductance,Induced MagneticField. **[4L+1T]**

### Maxwell'sEquationsandSolution

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]**

### PowerFlowandPoyntingVector

Poynting'stheorem,interpretationof𝐸⃗→×𝐻⃗→instantaneous,averageandcomplexPoyntingvector, powerlossinaplane conductor. **[6L+2T]**

### Textbooksand References

1. D.J.Griffith,“IntroductiontoElectrodynamics”,4thedition,PrenticeHallIndia,2017.
2. J.D.Jackson,“ClassicalElectrodynamics”,3rdedition,WileyEastern,2007.
3. E.C.JordanandK.G.Balman,“ElectromagneticWavesandRadiatingSystems”,2ndedition, 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,“FundamentalsofElectromagnetics”,TataMcGrawHill,1982.
6. B.B.Laud,“Electromagnetics”,3rdedition,NewDelhiNewAgeInternational,2011.
7. MatthewN.O.SadikuandS.V.Kulkarni,“PrinciplesofElectromagnetics”,6thEdition,Oxford University Press, 2015.

# PH409:BasicAnalogandDigitalElectronics(3-0-0:3)

### IntroductionandSurveyofNetworkTheorems

Thevnin,Nortontheoremsandnetworkanalysis,constant current andconstant voltagesources,power supplies, AC and DC bridges, rectifier circuits, transistors at low and high frequencies. **[7L]**

### ElectronicDevices

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]**

### IntegratedCircuit

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,multistageamplifiers,feedbacktheory. **[8L]**

### OperationalAmplifier

Basic differential amplifier circuit, operational amplifier characteristics and applications, simple analogcomputer,analogintegratedcircuits,waveshapingcircuits,multivibrators. **[5L]**

### DigitalElectronics

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]**

### Textbooksand References

1. C. K. Alexander and M. N.O. Sadiku, “Fundamentals of Electric Circuits”,6th edition, McGrawHill Education, 2019..
2. J.MillmanandA.Grabel,“Microelectronics”,2ndedition,McGrawHill,2017.
3. J.J.Cathey,“Schaum'sOutlineofElectronicDevicesandCircuits”,2ndedition,McGrawHill, 2002.
4. M.Forrest,“ElectronicSensorCircuitsandProjects”,MasterPublishingInc,2006.
5. W.Kleitz,“DigitalElectronics:APracticalApproach”,2ndedition,PrenticeHall,1989.
6. A.Malvino, andD.Bates,“ElectronicPrinciples”,7thEdition,McGrawHillEducation,New Delhi, 2017.

# PH481:ElectronicsLaboratory-I(0-0-6:3)

* 1. TostudyCEamplifier
	2. ToStudyaRCcoupledamplifier(twostage amplifier)
	3. Op-AmpArithmeticOperations
		1. adder,
		2. subtractor
		3. integrator
		4. differentiator
	4. Op-Ampsquare,triangleandsawtoothgeneratorusingWienBridgeOscillator
	5. TostudysignalconditioningcircuitsusingOp-Amp
		1. currenttovoltageconverter
		2. voltagetocurrentconverter
		3. voltagetofrequencyconverter
	6. Tostudymonostable/astablegeneratorsusingIC555timer
	7. TostudyJK/RS/DFlipflop
	8. TostudythecharacteristicsofUJTandcalculatetherelaxationtime.
	9. TostudyADandDAcircuits
	10. TostudyandconstructtheK-mapofthegivenBoolenexpression
	11. TorealizeandstudytheShiftRegister.SerialinSerialout/SerialinParallelout/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,“ExperimentsinDigitalPrinciples”,3rdedition,McGrawHill,1986.

# PH402:MathematicalPhysics-II(3-1-0:4)

### ComplexAnalysis

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

### IntegralTransforms

Fourier and Laplace transform, inverse transforms, convolution theorem. Application of solvingODEsandPDEsbytransformmethods. **[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 relativisticquantummechanics. **[9L+3T]**

### Group Theory

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

### Textbooksand References

1. S.D.Joglekar,“MathematicalPhysics:AdvancedTopics”,UniversitiesPress.
2. A.W.Joshi,“MatricesandTensorsinPhysics”,NewAgeInternationalPrivateLimited.
3. A.W.Joshi,”ElementsofGroupTheoryforPhysicists”,NewAgeInternationalPublishers.
4. Arfken,WeberandHarris,“MathematicalMethodsforPhysicists”,AcademicPress.
5. Riley,HobsonandBence,“MathematicalMethodsforPhysicsand Engineering’’,Cambridge University Press.
6. A.Zee,“GroupTheoryinaNutshellforPhysicists”,PrincetonUniversityPress.
7. R.J.Beerends,H.G.TerMorsche,J.C.VanDenBerg,andE.M.VanDeVrie,“Fourierand Laplace Transforms”, Cambridge University Press.

# PH404:QuantumMechanics-II(3-1-0:4)

### SymmetriesandConservation 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]

### ApproximationMethods

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]**

### ScatteringTheory

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,resonancescattering. **[9L+3T]**

### IntroductiontoRelativisticQuantumMechanics

KleinGordonequation,Diracequation,negativeenergysolutions,antiparticles,Diracholetheory.

## [5L+2T]

### Textbooksand References

1. W.GreinerandB.Miller,“QuantumMechanics:Symmetries”,2ndedition,Springer,1994.
2. M.Beck,“QuantumMechanics:TheoryandExperiment”,1stedition,OxfordUniversityPress, USA, 2012.
3. R*.*Shankar,“PrinciplesofQuantumMechanics”,2ndEdition,PlenumPress,NewYork,2010.
4. J.J.Sakurai,“ModernQuantumMechanics”,2ndedition,AddisonWesley,2013.
5. W.Greiner,“RelativisticQuantumMechanics:WaveEquations”,3rdedition,Springer,2000.

# PH406:StatisticalMechanics(3-1-0:4)

### Reviewof Thermodynamics

Laws of thermodynamics, Carnot’s engine, Legendre transformations and thermodynamic potentials, Maxwellrelations. **[3L+1T]**

### StatisticalDescription

Macroscopicandmicroscopicstates,connectionbetweenstatisticalandthermodynamics.

### Ensemble

## [3L+1T]

Microcanonical ensemble: phase space, Liouville's theorem, applications of ensemble theory to classicaland quantumsystems; Canonical ensemble : partitionfunction, thermodynamics in canonical ensemble, ideal gas, energy fluctuations, statistics of paramagnetism, negative temperature; Grand canonical ensemble : equilibriumbetween a systemand a particle-energy reservoir, partition function, fluctuations, density matrices. **[9L+3T]**

### TheoryofQuantumIdealGases

Idealgasindifferentquantummechanicalensembles,identicalparticles,many-particlewave function, occupation numbers, classical limit of quantum statistics, molecules with internal motion.

## [6L+2T]

### BoseandFermi Gases

Ideal Bose Gas: Bose-Einstein condensation, Helium II, blackbody radiation, phonons; Ideal FermiGas:Pauliparamagnetism,Landaudiamagnetism,Whitedwarf. **[9L+3T]**

### InteractingSystems

Isingmodel,solutionofIsingmodel inonedimensionbytransfermatrixmethod,Meanfieldtheory.

## [6L+2T]

### Textbooksand References

1. R.K.PathriaandP.D.Beale,“StatisticalMechanics”,AcademicPress.
2. S.R.A.Salinas,“IntroductiontoStatisticalPhysics”,Springer.
3. K.Huang,“StatisticalMechanics”,JohnWileyAsia.
4. D.Y.Schroeder,“AnIntroductiontoThermalPhysics”,PearsonIndiaEducation.
5. W.Greiner,L.Neise,andH.Stocker,“ThermodynamicsandStatisticalMechanics”,Springer.
6. F.Reif.,“FundamentalsofStatisticalandThermalPhysics”,Levant Books.

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| --- | --- | --- |
| NITM.jpg | **NationalInstituteofTechnologyMeghalaya**An Institute of National Importance | CURRICULUM |
| Programme | **MasterofScienceinPhysics** | Yearof Regulation | 2019 |
| Department | **Physics** | Semester | II |
| CourseCode | CourseName | Credit Structure | MarksDistribution |
| L | T | P | C | INT | MID | END | Total |
| **PH 408** | **AppliedOptics** | **3** | **0** | **0** | **3** | **50** | **50** | **100** | **200** |
| SYLLABUS |
| No | Content | Hours |  |
| 1 | **PotentialsandFields**Potentialformulation,scalarandvectorpotential,gaugetransformation, Retardedpotential, Jefimenkoequations,Lienard-WeichartPotentials,Thefieldofamovingcharge,Radiationsfromdipoles | 8 |  |
| 2 | **Lasers and Optics** Interference, Michelson Interferometer, Fabry Perot Interferometer, Diffraction Integral, Basics ofLaser,Einsteincoefficients,Populationinversion,twoandthreelevelsystems,Totalinternalreflectionandevanescentwaves,Polarizationstates. | 8 |  |
| 3 | **FourierOptics**Spatialfrequency,Fouriertransformpropertyoflens,spatial-frequencyfiltering,phase-contrastmicroscope. | 5 |  |
| 4 | **GuidedWave Optics**Wavesbetweenparallelplanes,transmissionlinetheory.TMandTEwavesinrectangular guides, circular waveguide, attenuation factor and Q of waveguides. | 6 |  |
| 5 | **IntroductiontoOpticalFibers**Stepindex,gradedindexfibersandapplicationsofopticalfibers,photoniccrystals,bragg gratings | 5 |  |
| 6 | **AnisotropicMedia**Planewavesinanisotropicmedia,uniaxialcrystals,andsomepolarizationdevices. | 4 |  |
| **TotalHours** | 36 |  |
| **Textbooksand References** |
| A.Ghatak,“Optics”,McGraw Hill. |
| A.Ghatak&K.Thyagarajan,“OpticalElectronics”,NewDelhiCambridgeUniversityPress |
| R.S.Sirohi,“WaveOptics&itsApplications”,OrientLongman. |
| F.L.PedrottiandL.S.Pedrotti,“IntroductiontoOptics”,Prentice-Hall International. |
| J.W.Goodman,“IntroductiontoFourierOptics”,McGrawHill. |
| E.Hecht&A.R.Ganesan,”Optics”,NewDelhiPearson2008. |
| D.J.Griffith,“IntroductiontoElectrodynamics”,4thedition,PrenticeHallIndia,2017. |

# PH422:ComputationalProgramming(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.

### Textbooksand References

1. V.Rajaraman,“ComputerProgramminginC”,PHILearning.
2. B.Gottfried,“ProgrammingwithC”,Schaum'sOutlinesSeries.
3. B.W.KernighanandD.M.Ritchie,“TheCprogramminglanguage”,Prentice-Hall.
4. E. Balagurusamy “Programming in ANSI C”, 7th Edition, McGraw Hill Education India PrivateLimited

# PH482:GeneralPhysicsLaboratory(0-0-6:3)

1. HallEffectin Semiconductor
2. TwoProbeMethodforResistivityMeasurement.
3. Forbe’sMethod
4. Fourier Filtering
5. ElasticsConstants–EllipticalandHyperbolicFringes
6. Hysteresis(B–H Curve)
7. HelmholtzGalvanometer
8. ConductivityofThinFilm–FourProbeMethod
9. CurieTemperatureofMagneticMaterials
10. DielectricConstantandCurieTemperatureofFerroelectricCeramics

### References

1. R.A.Dunlop,“ExperimentalPhysics”,OxfordUniversityPress.
2. A.C.Melissinos,“ExperimentsinModernPhysics”,AcademicPress.

# PH501:AtomicandMolecularPhysics(3-1-0:4)

### OneElectronAtomandInteractionofRadiationwithMatter

Quantumstates, atomic orbital, parity of the wave function, angular and radial distribution functions, timedependentperturbation,interactionofanatomwithelectromagneticwave. **[6L+2T]**

### FineandHyperfineStructure

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, Hyperfineinteractionandisotope shift, hyperfine splittingofspectrallines,selection rules.**[9L+3T]**

### ManyElectronAtom

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]**

### MolecularElectronicStates

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]**

### RotationandVibrationofMolecules

Molecular rotation, molecular vibrations, Morse potential, pure vibrational transitions, pure rotational transitions, vibration- rotation transitions, electronic transitions, Franck-Condon principle, rotational structureofelectronictransitions,Fortrat diagram,dissociationenergyofmolecules,FTIRandRaman spectroscopy. **[6L+2T]**

### TextBooks&References

1. H.E.White,“IntroductiontoAtomicSpectra”,TataMcGrawHill.
2. C.B.Banwell,“FundamentalsofMolecularSpectroscopy”,TataMcGrawHill.
3. B.H.BransdenandC.J.Joachain,“PhysicsofAtomsandMolecules”,Pearson Education.
4. M.Born,“AtomicPhysics”,NewYorkDover Publications.
5. H.Herzberg,“SpectraofDiatomicMolecules”,Springer.
6. C.N.Banwell&E.M.McCash,“FundamentalsofMolecularSpectroscopy”,NewDelhiMGH.

# PH503:CondensedMatterPhysics(3-1-0:4)

### CrystalStructure

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, packingfractions, 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 discussiononneutronandelectrondiffraction. **[6L+3T]**

### PhononandLatticeVibrations

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’stheoryoflatticespecificheat.Anharmoniceffects. **[6L+2T]**

### FreeElectronTheoryandEnergy 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

Formationofbands,bandgap,intrinsiccarrierconcentration,conceptofahole,impurity conductivity, Fermi level, direct and indirect band gap, p-n junction, drift current, diffusion current.

## [6L+2T]

### MagneticPropertiesofSolids

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 ofBCStheory,JosephsonJunction, SQUIDS. **[6L+1T]**

### Textbooksand References

1. N.W.AshcroftandN.Mermin,“SolidStatePhysics”,Brooks.
2. C.Kittel,“IntroductiontoSolidStatePhysics”,Wiley.
3. A.J.Dekkar,“SolidStatePhysics”Macmillan&CoLtd.
4. J.R.Christman,“FundamentalsofSolidStatePhysics”,JohnWiley&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.WertandR.M.Thomson,“PhysicsofSolids”,McGraw-HillBookCompany.
7. J.P.Srivastava,“ElementsofSolidStatePhysics”,PrenticeHall India.

# PH505:Nuclear&ParticlePhysics(4-0-0:4)

### NuclearProperties

Thenuclearradius,massandabundanceofnuclides,nuclearbindingenergy,nuclearangular momentumandparity,nuclearelectromagneticmoments,nuclearexcitedstates. **[6L]**

### TheForcebetweenNucleonsandNuclearModels

Deuteron,proton-protonandneutron-neutroninteraction,propertiesofthenuclearforce,exchange force model, shell model, even–Z, even-N nuclei and collective structure, realistic nuclear models.

## [10L]

### RadioactiveDecay

Radioactive decay law, production and decay of radioactivity, growth of daughter activities, types of decays,naturalradioactivity,alphadecay,betadecay,gammadecay. **[9L]**

### NuclearReactions

Typesofreactionandconservationlaws,isospin,nuclearfission,nuclearfusion. **[7L]**

### Detectorsand 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]**

### ParticlePhysics

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

### TextBooksandReferences

1. K.Heyde,“BasicIdeasandConceptsinNuclearPhysics:AnIntroductoryApproach”, 3rdedition, CRC Press, 2004.
2. J.L.Basdevant,J.RichandM.Spiro“FundamentalsinNuclearPhysics”,1stedition,Springer, 2005.
3. W.GreinerandJ.A.Maruhn“NuclearModels”,Springer,2009
4. S.Tavernier,“ExperimentalTechniquesinNuclearandParticlePhysics”,Springer, 2014
5. M.Thomson,“ModernParticlePhysics”,CambridgeUniversityPress,2016.
6. FI.Stancu,“GroupTheoryinSubnuclearPhysics”,1stedition,OxfordSciencePublications,1996.

# PH581:OpticsLaboratory(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. **MichelsonInterferometer**:MeasurementofWavelengthandRefractiveindex.
4. **KerrEffect:**Quadraticelectro-opticeffect.
5. **Zeeman Effect**: Studythesplittingof degenerateenergylevels in mercuryunder application ofa strong magnetic field.
6. **Fabry-PerotEtalon**:Veryprecisemeasurementofthewavelengthofaspectral 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 spint/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.

### TextBooks*&*References

1. N.Menn,“PracticalOptics”,ElsevierAcademicPress.
2. H.S.Hans,“NuclearPhysics:ExperimentalandTheoretical”,NewAgeInternational.
3. R.S.Sirohi,“ACourseofExperimentswithHe-NeLaser”,NewAge International.

**Elective-I**

# PH521:Light-MatterInteraction(3-0-0:3)

### ClassicalandSemi-classicalTreatmentofLight-MatterInteraction

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, energyand phase relaxation. **[9L]**

### NonlinearOptics

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]**

### UltrafastOptics

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,introductiontocoherent control. **[9L]**

### Nano-photonicsandMetamaterials

Metal optics, propagating and localized surface plasmons, effective medium theories, transformation optics,recentexperimentsinlinearandnonlinearmetamaterials. **[9L]**

### TextBooksandReferences

1. C.C.Tannoudji,J.D.Roc,andG.Grynberg,“Atom-PhotonInteractions:BasicProcessesand Applications”, Wiley-VCH.
2. P.E.Powers,“FundamentalsofNonlinearOptics”,CRCPress.
3. A.Weiner,“UltrafastOptics”,JohnWiley&Sons.
4. B.E.A.SalehandM.C.Teich,“FundamentalsofPhotonics”,JohnWiley&Sons.
5. R.W.Boyd,“NonlinearOptics",AcademicPress.
6. P.MeystreandM.Sargent,“ElementsofQuantumOptics”, Springer.

# PH523:Spintronics(3-0-0: 3)

### Historyof Spin

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

### QuantumMechanicsofSpin

Pauli spin matrices, the Pauli equation and spinors, more on the Pauli equation, extending the Pauliequation,theDirac equation. **[2L]**

### SpinOrbit Interaction

Spinorbitinteractioninsolid,Rashbainteraction,Dresselhausinteraction. **[3L]**

### ExchangeInteraction

Directexchange,indirectexchange,superexchangeinteraction,doubleexchange,RKKYexchange interaction. **[2L]**

### SpinRelaxation

Elliott-Yafet mechanism, D’yakonov Perel’ mechanism, Bir-Aronov-Pikus mechanism, hyperfine interactionwithnuclearspin. **[4L]**

### SpinDependentElectronTransport

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]**

### SpinTransferTorqueanditsMagnetic Dynamics

Spin injection phenomena, dynamics of domain wall, magnetoresistance, giant magnetoresistance (GMR),tunnelmagnetoresistance(TMR). **[7L]**

### ApplicationtoSpintronics

Spin photoelectronic devices, magnetic tunnelingdevices, spin qubits, Quantumspin halleffect, band inversion, strained semiconductor, HgTe-CdTe quantum well. **[7L]**

### TextBooksandReferences

1. S.BandyopadhyayandM.Cahay,“IntroductiontoSpintronics”,CRCPress.
2. Y.Xu,D.D.AwschalomandJ.Nitta,“HandbookofSpintronics”,Springer.
3. T.Dieti,D.D.Awschalom,M.KaminskaandH.Ohno,“Spintronics”,AcademicPress.
4. T.Shinjo,“NanomagnetismandSpintronics”,Elsevier.
5. C.FelserandG.H.Fecher,“Spintronics”,Springer.
6. M.Johnson,“Magnetoelectronics”,AcademicPress.

# PH525:BiologicalPhysics (3-0-0: 3)

### PhysicalBiology

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, theunifying ideas of biology, mathematical toolkit, biology by the numbers, cells and their contents: an ode to E. Coli, cells and structures within them. **[7L]**

### ThermodynamicsofLivingSystems

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]

### DynamicsofBiomolecules

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, biologicalstatisticaldynamics,molecularmotors,translationalmotors:myosin,biasedrandomwalk. **[8L]**

### BiologicalElectricity&QuantumBiology

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]**

### PhysicalMethodsinBiologyandMedicine

1. ray crystallography, fluorescence spectroscopy, electron microscopy, nuclear magnetic resonance, atomicforcemicroscopy,tomography,sonograms,radiationtherapy,pacemakers. **[5L]**

### TextBooks&References

* 1. P.Nelson,“BiologicalPhysics:Energy,Information,Life”,W.H.Freeman.
	2. R.Cotterill,“Biophysics:AnIntroduction”,Willey.
	3. R.Glaser,“Biophysics”,Springer.
	4. R.NossalandH.Lecar,“Molecular&CellBiophysics”,Addison-Wesley.
	5. C.R.CantorandP.R.Schimmel,“BiophysicalChemistry:vol.I,II&III”,W.H. Freeman.

# PH527:PhaseTransitionsandCriticalPhenomena(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

Thespin-1/2Isingmodel,spin-1Isingmodel,qstatePottsmodel,X-Ymodel,Heisenbergmodel.

## [5L]

### Meanfieldtheories

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]**

### Seriesexpansions

Seriesexpansion,applicationstoIsingmodel. **[4L]**

### MonteCarlosimulations

Importancesampling,Metropolisalgorithm,erroranalysis. **[5L]**

### Therenormalizationgroup

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

### TextBooks&References

1. H.E.Stanley,“IntroductiontoPhaseTransitionsandCriticalPhenomena”,OxfordUniversity Press.
2. J.M.Yeomans,“StatisticalMechanicsofPhaseTransitions”,OxfordUniversityPress.
3. D.Chandler,“IntroductiontoModernStatisticalMechanics”,OxfordUniversityPress.
4. R.K.PathriaandP.Beale,“StatisticalMechanics”,AcademicPress.
5. M.PlischkeandB.Bergersen,“EquilibriumStatisticalPhysics”,Wspc.

# PH529:Non-EquilibriumStatisticalMechanics(3-0-0:3)

### Introduction

Correlationfunctions,Responsefunctions,theharmonicoscillator,dissipation,elasticwavesand phonons. **[6L]**

### Diffusion

Fick’slaw,Brownianmotion,Langevintheory,Fokker-PlanckandSmoluchowskiequations. **[10L]**

### Fluctuationdissipation

Fluctuationdissipationtheorem,examplesofmagneticsystemsinpresenceofamagneticfield. Inelasticscattering, Onsager relations, Neutron scattering, scatteringof charged particles and photons.

## [10L]

### Linearresponse

Linearresponsetheory,current-currentcorrelator,Kuboformula,SpinDynamics,Ferroand Antiferromagnets, Vortices in XY model, Crystal growth, Grain boundaries, dislocation and melting.

## [10L]

### TextBooks&References

1. R.K.PathriaandP.D.Beale,“StatisticalMechanics”, AcademicPress.
2. P.V.Panat,“ThermodynamicsandStatisticalmechanics”,Narosa.
3. V.Balakrishnan,“ElementsofNonequilibriumMechanics”,AneBooksPvt. Ltd.
4. L.E.Reichl,“AModernCourseinStatisticalPhysics”,Wiley -VCH.

4.Chaikin&Lubensky,“PrinciplesofCondensedMatterPhysics”,CambridgeUniversityPress.

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| --- | --- | --- |
| NITM.jpg | **NationalInstituteofTechnologyMeghalaya**An Institute of National Importance | CURRICULUM |
| Programme | **MasterofScienceinPhysics** | Yearof Regulation | 2019 |
| Department | **Physics** | Semester | III |
| CourseCode | CourseName | Credit Structure | MarksDistribution |
| L | T | P | C | INT | MID | END | Total |
| **PH 531** | **Nanoelectronics** | **3** | **0** | **0** | **3** | **50** | **50** | **100** | **200** |
| Course Objectives | To introduce the (i) electron dynamics in nanoscaledevicesand(ii)conceptsofsingle- electron tunnelling and its application. | Course Outcomes | CO1 | Understandthenanoelectronicsconceptsusingquantummechanics |
| CO2 | Analysetheelectrontransportphenomenaatthenanoscale level |
| CO3 | Understandtheworkingmechanismofsingle-electrontunneling |
| CO4 | Acquiretheabilitytodegignthe circuit and simulation innanoelectronics |
| SYLLABUS |
| No | Content | Hours | COs |
| 1 | **QuantumTheoryfor 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 | **ElectronDynamicsinNanoscaleDevices**Introductiontoelectrontransport,equilibriumGreen’sfunctioninelectrontransport,electriccurrentunderlinearresponse,GeneralKuboconductivity,non-equilibrium electrontransport, electron propagation- physics of Green’s function, device current formalism. | 10 | CO2 |
| 3 | **SingleElectron Tunneling**Tunneling capacitor, Coulomb blockade, quantum dot circuit, double junction system,Single-ElectronTransistor(SET),impulsecircuitmodelforSET:ZeroandnonzerotunnelingtimeSETcircuit examples. | 10 | CO3 |
| 4 | **CircuitDesignandSimulation**Challengesofcircuitdesign,signalamplification,biasingandcoupling, SPICEmodel,the introduction of fuzzy logic and neural networks for circuit design. | 10 | CO4 |
| **TotalHours** | 36 |  |
| **EssentialReadings** |
| 1. J.Hoekstra,“IntroductiontoNanoelectronicSingle-ElectronCircuitDesign”,PanStanfordPublishingPte. Ltd.
2. S.G.TanandMansoorB.A.Jalil,“Introductiontothephysicsofnanoelectronics”,WoodheadPublishingLimited.
3. G.W.Hanson,“FundamentalsofNanoelectronics”,PearsonIndia.
 |
| **SupplementaryReadings** |
| 1. JoachimKnoch,“Nanoelectronics:DevicePhysics,Fabrication,Simulation”,DeGruyterOldenbourg.
 |

**Elective–II&III**

# PH522:MeasurementTechniquesandCryogenics(3-0-0:3)

**Kinetic Theory of Gases**: Behaviour of gases, pressure of gases, Maxwell’s law, gas transport phenomenon;viscous,molecularandtransitionflowregimes. **[4L]**

**Vacuum Generation**:Measurement of pressure, residual gas analyses; production of vacuum - mechanical pumps, rotary vane pumps, diffusion pump, cryopumps, turbo-molecular pumps, getter andionpumps,choiceofpumpingprocess. **[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,principlesofnoisecontrol,silencersandtheirtypes. **[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 He3 refrigerator, He4 refrigerator, cryostat design; cryogenic level sensors, handling of cryogenic liquids; cryogenic fluid storage*,* insulations, cryogenic fluid transfer systems*,* cryogenic thermometry. **[10L]**

### Textbooksand References

1. D.M.Hoffman,B.SinghandJ.H.Thomas,“HandbookofVacuum ScienceandTechnology”, Academic Press Limited.
2. J.M.Lafferty,“FoundationsofVacuumScienceandTechnology”,Wiley-Blackwell.
3. V.V.Kostionk,“ATextBookOfCryogenics”,DiscoveryPublishingHouse.
4. T.M.Flynn,“CryogenicEngineering”,MarcelDekker.
5. P.V.EMcClintock,D.J.MeredithandJ.K.Wigmore,*“*Low-temperaturePhysics:An Introduction for Scientists and Engineers”*,* Springer Science.

# PH524:NumericalMethodsandComputationalPhysics(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 pointcomplications,overflowandunderflow. **[6L]**

### MatricesandLinearAlgebraic Equations

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

### RootFindingandNonlinearSetsof Equations

Bisectionmethod,Newton–Raphsonmethod,Secantmethod,applications. **[4L]**

### Interpolation

Lagrangepolynomials. **[2L]**

### ModelingofData

Leastsquarefittingoffunctionsanditsapplications. **[4L]**

### Numericaldifferentiation

Forward,backwardandcentreddifferenceformula. **[4L]**

### Solutionofordinarydifferentialequations

Euler’s method, second and fourth order Runge-Kutta methods, finite difference method, boundary value problems. **[5L]**

### Numericalintegration

Trapezoidal,SimpsonandGaussianQuadraturesrules,applications. **[3L]**

### Monte-Carlomethods

Randomnumbergeneration,checkingtherandomnessofasequence,Monte-Carlointegration. **[3L]**

### TextBooksandReferences

1. V.Rajaraman,“ComputerOrientedNumericalMethods”,PHILearningPublishers.
2. R.L.BurdenandJ.D.Faires,“NumericalAnalysis”,BrooksColePublishing.
3. K.P.N.Murthy,“Monte-CarloMethodsinStatisticalPhysics”,UniversityPress.
4. H.T.DavisandK.T.Thomson,“LinearAlgebraandLinearOperatorsinEngineeringwith Applications In Mathematica”, Academic Press.
5. R.L.BurdenandJ.DouglasFaires,“NumericalAnalysis”,Thomson Learning

# PH528:ComputationalLab(0-0-6:3)

1. Uniformrandomnumbergeneration–ParkandMillermethod
2. Gaussianrandomnumbergeneration–BoxandMullermethod
3. Matrixaddition,subtractionandmultiplication
4. Transposeofa matrix
5. Rootsofalgebraicequations–Newton–Raphson method
6. Least-squarescurvefitting–Straight-linefitandExponentialfit
7. Solutionofsimultaneouslinearalgebraicequations–Gausseliminationmethod
8. Solutionofsimultaneouslinearalgebraicequations –Gauss-Seidel method
9. Interpolation–Lagrangemethod
10. Numericaldifferentiation
11. NumericalIntegration–Trapezoidal,SimpsonandGaussianQuadraturesrules
12. Solutionofordinarydifferentialequations–Runge-Kutta2nd/4thorder method
13. MonteCarlosimulationofIsingmodel

### TextBooksandReferences

1. G.L.Squires,“PracticalPhysics”,CambridgeUniversityPress.
2. V.Rajaraman,“ComputerOrientedNumericalMethods”,PHILearningPublishers.
3. H.M.Antia,“NumericalMethodsforScientistsandEngineers”,HindustanBookAgency.
4. K.P.N.Murthy,“Monte-CarloMethodsinStatisticalPhysics”,UniversityPress.

**Elective –IV**

# PH542:ScienceandTechnologyofThinFilms(3-0-0:3)

### ThermodynamicsofEvaporation

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]**

### PhysicalVaporDeposition

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 sputteringsystems,reactivesputtering. **[8L]**

### ChemicalVaporDeposition

Gasflowsystem,reactionchemistryandthermodynamicsofCVD;thermalCVD,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]**

### SubstratePreparationandThicknessMeasurement

Contaminationandcleaningprocess,chemicaletching,physicaletching,andetchinginduceddamage. ThicknessmeasurementbyTalystep,quartzcrystalmicrobalance,andopticalmethods. **[4L]**

### TextBooksandReferences

1. K.S.S.Harsha,“PrinciplesofPhysicalVaporDepositionofThinFilms”,Elsevier.
2. D.L.Smith,“Thin-FilmDeposition:PrinciplesandPractices”,McGraw-HillEducation.
3. M.L.HitchmanandK.F.Jensen,“ChemicalVaporDeposition:PrinciplesandApplications”, Academic Press.
4. D.Kashchiev,“Nucleation:BasicTheorywithApplications”,Butterworth-Heinemann.
5. H.H.Gatzen,V.SaileandJ.Leuthold, “MicroandNanoFabrication:ToolsandProcesses”, Springer.

# PH544:NanoscienceandTechnology(3-0-0:3)

### BackgroundtoNanotechnology

Scientific revolution, physics of low-dimensional materials, atomic structures, 1D, 2D and 3D confinement,densityof states,excitons,emergenceofnanotechnology,challengesinnanotechnology. Carbon age: new form of carbon (from graphene sheet to CNT). Risks and benefits of nanomaterials.

## [6L]

### DifferentClassesof Nanomaterials

Carbon nanotubes (CNT), metals (Au, Ag), metal oxides (TiO2, CeO2, ZnO), semiconductors (Si, Ge, CdS, ZnSe), ceramics and composites, dilute magnetic semiconductor, size dependent properties, mechanical,physicalandchemical properties. **[6L]**

### NanostructureFabrication

Top-downapproach:Lithography.Bottom-upapproach:PVD&CVD. **[8L]**

### Nanoelectronics

Tunneljunction,Coulomb blockadeandsingleelectrontransistor:operatingprinciple,technologyand application,carbonbaseddevices. **[8L]**

### Nanobiotechnology

Protein-basednanostructures,engineerednanopores,DNA-basednanostructures,Nanoparticle– biomaterialhybridsystemsforbioelectronicdevices,DNA-goldnanoparticleconjugates. **[8L]**

### TextBooksandReferences

1. M.Kuno,“IntroductoryNanoscience:PhysicalandChemicalConcepts”,GarlandScience.
2. H.H.Gatzen,V.SaileandJ.Leuthold,“MicroandNanoFabrication:ToolsandProcesses”, Springer.
3. G.W.Hanson,“FundamentalsofNanoelectronics”,Pearson.
4. C.M.NiemeyerandC.A.Mirkin,“NanobiotechnologyConcepts,ApplicationsandPerspectives”, Wiley-VCH.

# PH546:PhysicsofLiquidCrystals(3-0-0:3)

### ClassificationofLiquidCrystals

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, magneticresonance,electronspinresonance,RamanscatteringandX-raydiffraction. **[6L]**

### TheoriesofLiquidCrystallinePhaseTransition

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]**

### ContinuumTheory

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]**

### DynamicalPropertiesofNematic

The equations of nemato-dynamics, laminar flow, molecular motions, optical properties of cholesterics,optical propertiesofideal helices,agentinfluencingthepitch,liquidcrystaldisplay. **[6L]**

### FerroelectricLiquidCrystals

The properties of smectic C continuum description smectic C- smectic A transitionapplications. Discotic liquid crystals: symmetry and structure, mean field description of discotic liquid crystals, continuumdescription,lyotropicliquidcrystalsandbiologicalmembrane. **[6L]**

### ApplicationsofLiquidCrystals

Liquid crystal applications in LCDs, switchable windows, demonstrations, non-display applications, thermochromicsandKevlar. **[6L]**

### TextBooksandReferences

1. S.Chandrasekhar,“LiquidCrystals”,CambridgeUniversityPress.
2. G.VertogenandW.H.deJeu,“ThermotropicLiquidCrystals:Fundamentals”,Springer.
3. P.G.deGennesandJ.Prost,“ThePhysicsofLiquidCrystals”,Clarendon Press.
4. P.J.CollingsandM.Hird,“IntroductiontoLiquidCrystals:PhysicsandChemistry”,Taylor and Francis.
5. D.YangandS.Wu,“FundamentalsofLiquidCrystalDevices”,Wiley.
6. S.T.Lagerwall,“FerroelectricandAntiferroelectricLiquidCrystals”,Wiley-VCH.

# PH552:QuantumInformationandComputation(3-0-0:3)

### FrameworkofQuantumMechanics

The Stern Gerlach experiment, Quantum State and the vector representation, fundamental postulates, operators, basic transformation, multipartite system, Tensor product and entangledstate,Cbitsand 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 systemand logic gates. The Bell state and EPR paradox. Testing Bell’s inequality. Three qubit system, quantumadder. QuantumGate: controlled-Ugate, controlled-V gate andToffolicgate.**[10L]**

### QubitsMeasurements

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]

### QuantumComputing

DiVincenzo criteriaand physical realizations. NMR quantumcomputer,single-spinand multi-spin Hamiltonian, Implementation of gates and algorithms, Qubit tomography. Quantum computing withtrappedionsandneutralatoms. **[10L]**

### TextBooksandReferences

1. O. A. Cross, “Quantum Mechanics and Quantum Computing Notes”, 1st edition, Create Space Independent Publishing Platform, 2017.
2. D.McMahon,“QuantumComputingExplained”,Wiley,2016.
3. M.NakaharaandT.Ohmi,“QuantumComputing:FromLinearAlgebratoPhysical Realizations”, 1st edition, CRC Press, 2008.
4. Vathsan, Radhika, “Introduction to Quantum Physics and Information Processing”, 1st edition, CRC Press, 2015.
5. N.DavidMermin,“QuantumComputerScience:AnIntroduction”,CambridgeUniversity Press, 2007.
6. M.A.NielsenandI.L.Chuang,“QuantumComputationandQuantumInformation”,10th edition, Cambridge University Press, 2010.