Indian Institute of Space Science and Technology

Department of Space, Govt. of India
Thiruvananthapuram

Dual Degree Program

Bachelor of Technology in Engineering Physics with
Master of Technology in Optical Engineering or
Master of Science in Solid State Physics

Curriculum and Syllabus

Semester – I

Code	Title	L	T	P	C
MA111	Calculus	3	1	0	4
PH111	Physics I	3	1	0	4
CH111	Chemistry	2	1	0	3
AE111	Introduction to Aerospace Engineering	3	0	0	3
MA112	Computer Programming and Applications	2	0	3	3
HS111	Communication Skills	2	0	3	3
PH131	Physics Lab	0	0	3	1
AE131	Basic Engineering Lab	0	0	3	1
	Total	15	3	12	22

Semester – II

Code	Title	L	T	P	C
MA121	Vector Calculus and Differential Equations	2	1	0	3
AV121	Data Structures and algorithms	3	1	0	4
PH121	Physics II	3	1	0	4
CH121	Material Science and Metallurgy	3	0	0	3
AV122	Basic Electrical and Electronics Engineering	3	1	0	4
AE141	Engineering Graphics	1	0	3	2
CH141	Chemistry Lab	0	0	3	1
	Total	15	4	6	21

Semester – III

Code	Title	L	T	P	C
MA211	Linear Algebra, Complex Analysis, and Fourier Series	3	0	0	3
PH211	Electrodynamics and Special Relativity	3	0	0	3
PH212	Mathematical Physics	3	1	0	4
AV211	Analog Electronic Circuits	3	0	0	3
PH213	Classical Mechanics	3	1	0	4
HS211	Introduction to Economics	2	0	0	2
PH231	Optics Lab I	0	0	3	1
	Total	17	2	3	20

Semester – IV

Code	Title	L	T	P	C
MA221	Integral Transforms, PDE, and Calculus of Variations	3	0	0	3
PH221	Modern Optics	3	0	0	3
PH222	Quantum Mechanics	3	1	0	4
AE225	Fluid Dynamics	3	0	0	3
AV223	Signals and Systems	3	0	0	4
AV227	Instrumentation and Measurement	3	0	0	3
HS221	Introduction to Social Science and Ethics	2	0	0	2
PH241	Optics Lab II	0	0	3	1
	Total	20	1	3	22

Semester – V

Code	Title	L	T	P	C
MA311	Probability, Statistics, and Numerical Methods	3	0	0	3
PH311	Atomic and molecular spectroscopy	3	1	0	4
PH312	Statistical Mechanics	3	0	0	3
AE315	Thermodynamics	3	0	0	3
HS311	Principles of Management Systems	3	0	0	3
PH331	Modern Physics Lab	0	0	6	2
AV337	Instrumentation and Measurement Lab	0	0	3	1
	Total	15	1	9	19

Semester – VI

Code	Title	L	T	P	C
PH321	Introduction to Solid State Physics	3	0	0	3
ES322	Introduction to Earth, Atmosphere and Ocean Sciences	3	0	0	3
ES323	Astrophysical Concepts	3	0	0	3
CH321	Environmental Science and Engineering	2	0	0	2
E01	Elective I	3	0	0	3
E02	Elective II	3	0	0	3
PH341	Solid State Physics Lab	0	0	3	1
PH351	Comprehensive Viva-Voce I	0	0	0	3
	Total	17	0	3	21

Elective I and II Courses

Code	Title	L	T	P	C
PH361	Quantum Information Theory	3	0	0	3
PH362	Non-linear Dynamics, Chaos and Fractals	3	0	0	3
ES361	Introduction to Remote Sensing	3	0	0	3
ES362	Geographic Information System	3	0	0	3
MA361	Computer Modelling and Simulation	3	0	0	3
MA362	Optimization Techniques	3	0	0	3
MA363	Artificial Neural Networks	3	0	0	3
AE361	Operations Research	3	0	0	3
AV489	Pattern Recognition and Machine Learning	3	0	0	3
AV490	Deep Learning for Computational Data Science	3	0	0	3
AV491	Advanced Sensors and Interface Electronics	3	0	0	3
AV493	Machine Learning for Signal Processing	3	0	0	3

Master of Technology in Optical Engineering

Semester – VII

Code	Title	L	T	P	C
PH411	Optical Engineering Fundamentals	3	0	0	3
PH412	Opto Mechanical Design Analysis	3	0	0	3
Ph413	Optical Fabrication and Testing	3	0	0	3
PH414	Lasers and Optoelectronics	3	0	0	3
PH419	Fourier Optics	3	0	0	3
PH431	Optics and Optoelectronics Lab	0	0	3	1
PH432	Design and Analysis Lab	0	0	3	1
PH452	Summer Internship and Training	0	0	0	3
	Total	15	0	6	20

Semester – VIII

Code	Title	L	T	P	C
PH421	Guide Wave Optics and Optical Communication	3	0	0	3
PH422	Adaptive Optics	3	0	0	3
PH423	Optical System Analysis and Design	3	0	0	3
PH4xx	PG Elective I	3	0	0	3
PH4xx	PG Elective II	3	0	0	3
PH441	Guided Wave Optics Lab	0	0	3	1
PH442	Adaptive Optics Lab	0	0	3	1
PH451	Seminar	0	0	0	1
	Total	15	0	6	18

Semester – IX

Code	Title	L	T	P	C
PH551	Project Phase I	0	0	0	13
PH552	Comprehensive Viva-Voce II	0	0	0	2
	Total	0	0	0	15

Semester – X

Code	Title	L	T	P	C
PH554	Project Phase II	0	0	0	20
	Total	0	0	0	20

Semester-wise credits

Semester	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Credits	22	20	20	22	19	21	20	18	15	20	197

List of PG Electives

Code	Title	L	T	P	C
PH461	Optical Thin Films Science and Technology	3	0	0	3
PH462	Optical and Electro-Optical Sensors	3	0	0	3
PH463	Integrated Optics	3	0	0	3
PH464	Introduction to Quantum Optical Technologies	3	0	0	3
PH465	Advanced Optoelectronics	3	0	0	3
PH466	Statistical and Quantum Optics	3	0	0	3
PH467	Non-Linear Optics	3	0	0	3
PH468	MEMS and MOEMS	3	0	0	3
PH469	Laser Applications	3	0	0	3
PH470	Quantum Optical Communication	3	0	0	3
PH471	Nano Optics	3	0	0	3
PH361	Quantum information Theory	3	0	0	3

Master of Science in Solid State Physics

Semester – VII

Code	Title	L	T	P	C
PH415	Advanced Solid State Physics	3	1	0	4
PH416	Quantum Mechanics II	3	1	0	4
PH417	Semiconductor Physics	3	0	0	3
PH418	Experimental Physics	2	0	3	3
E03	Institute Elective	3	0	0	3
PH433	Solid State Physics Lab II	0	0	3	1
PH452	Summer Internship and Training	0	0	0	3
	Total	14	2	6	21

Semester – VIII

Code	Title	L	T	P	C
PH424	Advanced Statistical Mechanics	3	1	0	4
PH425	Computational Physics	2	0	3	3
PH4xx	PG Elective I	3	0	0	3
PH4xx	PG Elective II	3	0	0	3
PH453	Mini Project	0	0	0	2
PH443	Solid State Physics Lab III	0	0	3	1
PH454	Comprehensive Viva-Voce II	0	0	0	2
	Total	11	1	6	18

Semester – IX

Code	Title	L	T	P	C
PH553	Project Phase I	0	0	0	16
	Total	0	0	0	16

Semester – X

Code	Title	L	T	P	C
PH555	Project Phase II	0	0	0	18
	Total	0	0	0	18

Semester-wise credits

Semester	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Credits	22	20	20	22	19	21	21	18	16	18	197

PG Elective Courses

Code	Title	L	T	P	C
PH464	Optical Communication	3	0	0	3
PH465	Advanced Optoelectronics	3	0	0	3
PH467	Non-linear Optics	3	0	0	3
PH468	MEMS and MOEMS	3	0	0	3
PH469	Laser Applications	3	0	0	3
PH470	Quantum Optical Communication	3	0	0	3
PH472	Quantum Many-Body Physics	3	0	0	3
PH473	Device Physics and Nanoelectronics	3	0	0	3
PH474	Atomic and Molecular Spectroscopy	3	0	0	3
PH475	Cold Atoms and Bose-Einstein Condensates	3	0	0	3
PH476	Principles of Magnetic Resonance	3	0	0	3
PH477	High Resolution NMR Spectroscopy in Solids	3	0	0	3
PH478	Solid State NMR Spectroscopy: Techniques	3	0	0	3
PH479	Solid State NMR Studies in Condensed Matter	3	0	0	3

Course Syllabus

Semester – I

MA111	Calculus	(3 – 1 – 0) 4 credits

Sequence and Series of Real Numbers: sequence – convergence – limit of sequence – non-decreasing sequence theorem – sandwich theorem (applications) – L'Hopital's rule – infinite series – convergence – geometric series – tests of convergence (nth term test, integral test, comparison test, ratio and root test) – alternating series and conditional convergence – power series.

Differential Calculus: functions of one variable – limits, continuity and derivatives – Taylor's theorem – applications of derivatives – curvature and asymptotes – functions of two variables – limits and continuity – partial derivatives – differentiability, linearization and differentials – extremum of functions – Lagrange multipliers.

Integral Calculus: lower and upper integral – Riemann integral and its properties – the fundamental theorem of integral calculus – mean value theorems – differentiation under integral sign – numerical Integration- double and triple integrals – change of variable in double integrals – polar and spherical transforms – Jacobian of transformations.

Text Books

1. Stewart, J., Calculus: Early Transcendentals, 5^{th} ed., Brooks/Cole (2007).
2. Jain, R. K. and Iyengar, S. R. K., Advanced Engineering Mathematics, 4^{th} ed., Alpha Science Intl. Ltd. (2013).

References

1. Greenberg, M. D., Advanced Engineering Mathematics, Pearson Education (2007).
2. James, G., Advanced Modern Engineering Mathematics, Pearson Education (2004).
3. Kreyszig, E., Advanced Engineering Mathematics, 9^{th} ed., John Wiley (2005).
4. Thomas, G. B. and Finney, R. L., Calculus and Analytic Geometry, 9^{th} ed., Pearson Education (2003).

PH111	Physics I	(3 – 1 – 0) 4 credits

Introduction to vectors: linear independence – completeness – basis – dimensionality – inner product – orthogonality – displacement – derivatives of a vector – velocity – acceleration – plane polar coordinates.

Angular momentum: angular momentum and torque on a single particle – angular momentum and torque on a system of particles – moment of inertia – angular momentum of a rigid body

Planetary motion: central force motion of two bodies – relative coordinates – reduction to one dimensional problem – spherical symmetry and conservation of angular momentum, consequences – planetary motion and Kelpler's laws

Oscillations: Simple pendulum – 1-D harmonic oscillator – damped and forced harmonic oscillators – resonance

Special Relativity: Einstein's correction – Space-time interval – length contraction – time dilation - four vectors – displacement – velocity – acceleration – Lorentz transformation – conservation of 4-momentum – Mass energy relation

Modern Physics: Photo electric effect - blackbody radiation - wave matter duality - uncertainty principle -

Compton scattering

Text Books

1. Kleppner, D. and Kolenkow, R. J., An Introduction to Mechanics, 2nd ed., Cambridge Univ. Press (2013).

References

1. Serway, R. A. and Jewett, J. W., Principles of Physics: A Calculus Based Text, 5th ed., Thomson Brooks/Cole (2012).
2. Halliday, D., Resnick, R., and Walker, J., Fundamentals of Physics, 9th ed., John Wiley (2010).
3. Young, H. D., Freedman, R. A., Sundin, T. R., and Ford, A. L., Sears and Zemansky's University Physics, 13th ed., Pearson Education (2011).

CH111 Chemistry (2 – 1 – 0) 3 credits

Chemical Kinetics: basic concepts of chemical kinetics – complex reactions – effect of temperature on reaction rates – catalysis.

Electrochemical Systems: introduction to electrochemistry – different types of electrodes – half cell potential – electromotive force – Gibbs free energy and cell potential – Nernst equation – electrochemical series – classification of electrochemical cells.

Corrosion Science: definition – causes and consequences – significance and methods of corrosion control – mechanisms and theories of corrosion.

Spectroscopy: fundamentals of spectroscopy – electronic spectroscopy – vibrational spectroscopy – other spectroscopic techniques.

Propellants: classification of propellants – performance of propellants and thermochemistry– liquid propellants – oxidizers and fuels – solid propellants – composite solid propellants – propellant processing.

Text Books

1. Atkins, P. and de Paula, J., Atkins' Physical Chemistry, 9th ed., Oxford Univ. Press (2009).

References

1. Laidler, K. J., Chemical Kinetics, 3rd ed., Pearson Education (2005).
2. Kemp, W., Organic Spectroscopy, Palgrave Foundations (1991).
3. Revie, R. W. and Uhlig, H. H., Corrosion and Corrosion Control – An Introduction to Corrosion Science and Engineering, 4th ed., Wiley (2008).
4. Bockris, J. O'M. and Reddy, A. K. N., Modern Electrochemistry 1: Ionics, 2nd ed., Springer (1998).

AE111 Introduction to Aerospace Engineering (3 – 0 – 0) 3 credits

History of aviation – standard atmosphere – aerodynamic forces – lift generation – airfoils and wings – drag polar – concept of static stability – anatomy of an aircraft – mechanism of thrust production – propellers – jet engines and their operation – helicopters – aircraft performance – simple manoeuvres – aerospace materials and structural elements – aircraft instruments.

Elements of rocket propulsion – launch vehicle dynamics – basic orbital mechanics – satellite applications and orbits – future challenges in aerospace engineering.

Text Books

Same as Reference

References

1. Anderson, D. F. and Eberhardt, S., Understanding Flight, 2nd ed., McGraw-Hill (2009).
2. Anderson, J. D., Introduction to Flight, 7th ed., McGraw-Hill (2011).
3. Szebehely, V. G. and Mark, H., Adventures in Celestial Mechanics, 2nd ed., Wiley (1998).
4. Turner, M. J. L., Rocket and Spacecraft Propulsion: Principles, Practice and New Developments, 3rd ed., Springer (2009).

AV111 Basic Electrical Engineering (3 – 0 – 0) 3 credits

Circuit analysis, Kirchoff's law, mesh and nodal methods – transient analysis for RLC circuit – alternating current theory – resonance, Q factor and power measurement by two wattmeter circuits – network theorems – magnetic circuit, principles of magnetic circuits – DC and AC excitation – hysteresis loop, BH curve – losses, energy, and force production – Introduction to electrical machines: classification – operating principle – applications.

Textbooks:

1. Hughes, E., Electrical and Electronic Technology, Pearson Education (2002).
2. Deltoro, V., Principles of Electrical Engineering, 2nd ed., Prentice Hall (1986).

References:

1. Mittle, V. N. and Mittal, A., Basic Electrical Engineering, 2nd ed., Tata Mcgraw- Hill (2006).
2. Cotton, H., Principles of Electrical Engineering, Sir Isaac Pitman & Sons (1967).
3. Hayt, W. H. and Kemmerley, J. E., Engineering Circuit Analysis, 4th ed., McGraw- Hill (1986).
4. Murthy, K. V. V. and Kamath, M. S., Basic Circuit Analysis, Jaico Publishing (1998).
5. Kothari, D. P. and Nagrath, I. J., Theory and Problems of Basic Electrical Engineering, Prentice Hall (2000).
6. Pal, M. A., Introduction to Electrical Circuits and Machines, Affiliated East–West Press (1975).

HS111 Communication Skills (2 – 0 – 3) 3 credits

Functional English: conversation skills – asking questions, requests, doubts, engage in conversation – different types of communication-verbal and non-verbal, body language.

Teaching Grammar: grammar games, exercise.

Teaching Vocabulary: Language games, exercise.

Reading and appreciating stories, poems, essays – listening and appreciating video lectures – comprehensive questions and answers.

Lab: Presentation skills – appreciation of videos, songs – role plays – debates – extemporizes – group presentations – introduction to technical writing – technical writing, how to write minutes, report, and project proposal.

Text Books

Same as reference

References

1. Garner, A., Conversationally Speaking: Tested New Ways to Increase Your Personal and Social Effectiveness, McGraw-Hill (1997).
2. Bechtle, M., Confident Conversation: How to Communicate Successfully in Any Situation, Revell (2008).
3. Brown, S. and Smith, D., Active Listening with Speaking, Cambridge Univ. Press (2007).

PH131 Physics Lab (0 – 0 – 3) 1 credit

- ☐ Damped driven oscillator
- ☐ Waves and oscillation
- ☐ Modulus of elasticity
- ☐ Surface tension
- ☐ Moment of inertia and angular acceleration
- ☐ Faraday's law of induction
- ☐ Biot-Savarts law
- ☐ Ratio of electronic charge to mass
- ☐ Brewster's angle and Malu's law
- ☐ Earth's magnetic field
- ☐ Charge of an electron

Text Books

Lab Manual

AE131 Basic Engineering Lab (0 – 0 – 3) 1 credit

- Study of general purpose hand tools in workshop
- Assembly and disassembly practices of the following models
  - – Gear box assembly
  - – Centrifugal pump assembly along with shaft alignment practice
  - – Cam and follower mechanisms assembly
  - – Transducer (sensor) trainer
- Experiments on different basic machines
  - – Turning exercise – straight turning, taper turning, thread cutting practice
  - – Welding practice – arc welding
  - – Fitting practice – models with marking and drilling exercises
- Wiring and Soldering practices

Text Books

Lab Manual

Semester – II

MA121 Vector Calculus and Differential Equations (2 – 1 – 0) 3 credits

Vector Calculus: scalar and vector fields – level surfaces – directional derivatives, gradient, curl, divergence – Laplacian – line and surface integrals – theorems of Green, Gauss, and Stokes.

Sequences and Series of Functions: complex sequences – sequences of functions – uniform convergence of series – test for convergence – uniform convergence for series of functions.

Differential Equations: first order ordinary differential equations – classification of differential equations – existence and uniqueness of solutions of initial value problem – higher order linear differential equations with constant coefficients – method of variation of parameters and method of undetermined coefficients – power series solutions – regular singular point – Frobenius method to solve variable coefficient differential equations.

Special Functions: Legendre polynomials, Bessel's function, gamma function and their properties – Sturm-Liouville problems.

Text Books

1. Ross, S. L., Differential Equations, Blaisedell (1995).
2. Kreyszig, E., Advanced Engineering Mathematics, 9th ed., John Wiley (2005).
3. Stewart, J., Calculus: Early Transcendentals, 5th ed., Brooks/Cole (2007).

References

1. Greenberg, M. D., Advanced Engineering Mathematics, Pearson Education (2007).
2. Jain, R. K. and Iyengar, S. R. K., Advanced Engineering Mathematics, Narosa (2005).

MA122 Computer Programming and Applications (2 – 0 – 3) 3 credits

Introduction to Linux – introduction to programming – basic elements of a program, variables, values, types, assignment – expressions and control flow – iteration and loop design, arrays, for loop, functions, parameters, recursion – object-oriented paradigm, objects, classes, inheritance, reusability, polymorphism, overloading, libraries, containers, classes for file handling, parameter passing and pointers, linking, shell commands, data structures, linked list, stack, queue – applications.

Text Books

1. Lippman, S. B., Lajoie, J., and Moo, B. E., C++ Primer, 5th ed., Addison-Wesley (2012).
2. Lafore, R., Object-Oriented Programming in C++, 4th ed., Sams Publishing (2001).

References

1. Cohoon, J. P. and Davidson, J.W., Programming in C++, 3rd ed., Tata McGraw-Hill, (2006).
2. Bronson, G., A First Book of C++, 4th ed., Cengage (2012).
3. Stroustrup, B., The C++ Programming Language, 3rd ed., Pearson (2005).

PH121 Physics II (3 – 1 – 0) 4 credits

Electricity: curvilinear coordinates – conservative vector fields and their potential functions –Gauss' theorem, Stokes' theorem – physical applications in electrostatics – electrostatic po-tential and field due to discrete and continuous charge distributions – dipole and quadrupole moments – energy density in an electric field – dielectric polarization – conductors and capaci-tors – electric displacement vector – dielectric susceptibility.

Magnetism: Biot–Savart's law and Ampere's law in magnetostatics – magnetic induction due to configurations of current-carrying conductors – magnetization and surface currents – energy density in a magnetic field – magnetic permeability and susceptibility – force on a charged particle in electric and magnetic fields – electromotive force, Faraday's law of electromagnetic induction – self and mutual inductance, displacement current.

Maxwell's equations – charge and energy – Poynting's theorem – momentum – Maxwell's stress tensor – conservation of momentum – angular momentum.

Text Books

1. Griffith, D. J., Introduction to Electrodynamics, 3rd ed., Prentice Hall (1999).
2. Hecht, E., Optics, 4th ed., Pearson Education (2008).

References

1. Feynman, R. P., Leighton, R. B., and Sands, M., The Feynman Lectures on Physics, Narosa (2005).
2. Reitz, J. R., Milford, F. J., and Christy, R. W., Foundations of Electromagnetic Theory, 3 rd ed., Narosa (1998).
3. Wangsness, R. K., Electromagnetic Fields, 2nd ed., Wiley (1986).
4. Sadiku, M. N. O., Elements of Electromagnetics, 8th ed., Oxford Univ. Press (2007).

CH121 Materials Science and Metallurgy (3 – 0 – 0) 3 credits

Selection of materials – structure of solids, crystal structure – defects in crystals, free energy concept – alloying – principles of solidification – phase diagrams – concept of heat treatment – properties of materials, mechanical, electrical, thermal and optical properties – testing of materials – semiconductor materials – ceramics, synthesis and processing – polymers, classification, mechanism of formation, structure property relations, characterization – composites, classification, factors influencing properties, processing.

Text Books

1. Callister Jr.,W. D., Materials Science and Engineering: An Introduction, 7th ed., John Wiley (2007).
2. Raghavan V., Physical Metallurgy: Principles and Practice, 2nd ed., Prentice Hall (2006).

References

1. Billmeyer, F. W., Textbook of Polymer Science, 3rd ed., Wiley India (1984).
2. Askeland, D. R. and Phule, P. P., The Science and Engineering of Materials, 4th ed., Thompson-Engineering (2006).

AV121 Basic Electronics Engineering (3 – 0 – 0) 3 credits

Semiconductor diode characteristics – applications in rectifiers and power supplies – transistor characteristics.

Biasing circuit – bias stabilization and compensation techniques – small signal low frequency h-parameter model – low frequency transistors.

Amplifiers – FET biasing and low frequency amplifier circuits – RC-coupled amplifiers.

Introduction to operational amplifiers – inverting and non-inverting mode of its operation – dig-ital circuits – Boolean logic – basic gates – truth tables – logic minimization using K maps –combinatorial and sequential circuits.

Text Books

1. Boylestad, R. L. and Nashelsky, L., Electronic Devices and Circuit Theory, Pearson Education (2003).

2. Mano, M. M., Digital Design, Prentice Hall (2002).

References

1. Mottershed, A., Electronic Devices and Circuits: An Introduction, EEE Publication, 12th Indian ed. (1989).
2. Bapat, Y. N., Electronic Devices and Circuits, Tata McGraw-Hill, 9th ed. (1989).
3. Malvino, A. P., Electronic Principles, 12th ed., 3rd TMH ed., Tata McGraw-Hill (1989).
4. Jain, R. P., Modern Digital Electronics, McGraw-Hill (2004).
5. Floyd, T. L., Electronic Devices, Pearson Education, 8th ed. (2007).

AE141 Engineering Graphics (1 – 0 – 3) 2 credits

Introduction and importance of Engineering Graphics – sheet layout and free-hand sketching– lines, lettering and dimensioning – geometrical constructions – engineering curves – ortho-graphic projection – first angle and third angle projections – projection of points, straight lines and planes – projection of simple solids – sections of solids – development of surfaces – iso-metric projection – introduction to AutoCAD – creation of simple 2D drawings.

Text Books

1. Bhatt, N. D., Engineering Drawing: Plane and Solid Geometry, 50th ed., Charotar Publish- ing House (2010).

References

1. Jolhe, D. A., Engineering Drawing with an Introduction to AutoCAD, Tata McGraw-Hill(2008).
2. Venugopal, K. and Prabhu Raja, V., Engineering Drawing + AutoCAD, 5th ed., New Age International (2011).
3. Varghese, P. I., Engineering Graphics for Degree including AutoCAD, VIP Publishers(2012).
4. Luzadder, W. J. and Duff, J. M., Fundamentals of Engineering Drawing, 11th ed., Prentice Hall (1992).
5. Bethune, J. D., Engineering Graphics with AutoCAD, Prentice Hall, 2007.

CH141 Chemistry Lab (0 – 0 – 3) 1 credit

- Determination of total hardness of water
- The Nernst equation
- Potentiometry
- Conductometry
- Determination of phosphoric acid content in soft drink
- Determination of chloride content in water
- Validation of Ostwald's dilution law and solubility product
- Kinetics of acid hydrolysis of ester
- Kinetics of sucrose inversion
- Preparation of polymers
- Determination of molecular weight of polymers
- Metallography of steels

- ☐ Microhardness of different materials

Text Books

Lab Manual

AV141 Basic Electrical and Electronics Lab (0 – 0 – 3) 1 credit

Electrical Engineering Lab

- ☐ Magnetic measurements
- ☐ Three phase power measurement
- ☐ Verification of theorems
- ☐ Characteristic of electrical machines (AC and DC)

Electronics Engineering Lab

- ☐ Implementation of digital circuits
- ☐ Design of electronic system using operational amplifiers
- ☐ Device characteristic
- ☐ Power supply design
- ☐ Wave shaping circuits: clippers and clampers
- ☐ Biasing of transistor

Text Books

Lab Manual

Semester – III

MA211 Linear Algebra, Complex Analysis and Fourier Series (2 – 1 – 0) 3 credits

Linear Algebra: matrices; solution space of system of equations Ax = b, eigenvalues and eigenvectors, Cayley-Hamilton theorem – Definition of Group, ring field – Vector spaces over real field, sub-spaces, linear dependence, independence, basis, dimension – inner product –Gram–Schmidt orthogonalization process – linear transformation; null space and nullity, rangeand rank of a linear transformation.

Complex Analysis: complex numbers and their geometrical representation – functions of complex variable – limit, continuity and derivative of functions of complex variable – analytical functions and applications – harmonic functions – transformations and conformal mappings – bilinear transformation – contour integration and Cauchy's theorem – convergent series of analytic functions – Laurent and Taylor series – zeroes and singularities – calculation of residues – residue theorem and applications.

Fourier Series and Integrals: Expansion of periodic functions with period 2π – Fourier series of even and odd functions – half-range series – Fourier series of functions with arbitrary period– conditions of convergence of Fourier series. Fourier integrals.

Text Books

1. Kreyszig, E., Advanced Engineering Mathematics, 10th ed., John Wiley (2011).
2. Mathews, J. H. and Howell, R., Complex Analysis for Mathematics and Engineering, Narosa (2005).

References

1. Brown, J. W. and Churchill, R. V., Complex Variables and Applications, 9th ed., McGraw-Hill (2013).
2. Greenberg, M. D., Advanced Engineering Mathematics, Pearson Education (2007).
3. Jain, R. K. and Iyengar, S. R. K., Advanced Engineering Mathematics, Narosa (2005).
4. Churchill, R. V. and Brown, J. W., Complex Variables and Applications, 6th ed., McGraw- Hill (2004).

PH211 Electrodynamics and Special Relativity (3 – 0 – 0) 3 credits

Electromagnetic Waves:

Waves in one-dimension – Wave equation – sinusoidal waves – Reflection and transmission – Polarization – Electromagnetic waves in vacuum – wave equations for E and B – Monochromatic plane waves – Energy and momentum in electromagnetic waves – Electromagnetic Waves in Matter – Propagation in linear media – reflection and transmission at normal and oblique incidence – Absorption and Dispersion – Electromagnetic waves in conductors – reflection at a conducting surface – frequency dependence of permittivity – Guided Waves – wave guides – TE waves in a rectangular wave guide – waves in coaxial transmission line.

Potentials and Fields:

Scalar and vector potentials, gauge transformations – Coulomb gauge.

Radiation:

Dipole radiation – Electric and magnetic dipole radiation, radiation from an arbitrary source, Power radiated from point charges, Radiation reaction.

Electrodynamics and Relativity:

Special theory – Einstein's postulates – Geometry and structure of spacetime – Lorentz transformations. Relativistic mechanics – Propertime – Energy and Momentum – Kinematics and Dynamics; Relativistic electrodynamics – Magnetism as a relativistic phenomenon – field tensor – transformation of fields – Relativistic potentials.

Text Books

1. Introduction to Electrodynamics, D. J. Griffiths, Prentice Hall of India.

References

Same as Text Books

PH212 Mathematical Physics (3 – 1 – 0) 4 credits

Sketching functions, Gaussian integrals, Stirling's formula, Generalised functions: Step function, Dirac delta function, properties of delta function,
Vectors and Tensors: Cartesian tensors, covariant and contravariant components of a vector, covariant and contravariant tensor, mixed tensor, metric tensor, contraction, rotations and index notation, Isotropic tensors: Kronecker delta, Levi-Civita symbol, Gram determinant. Rotations in three dimensions, Proper and improper rotations, scalars and pseudoscalars; polar and axial vectors.
Linear vector spaces: Definitions and basic properties, the dual of a linear space, the inner production of two vectors, basis sets and dimensionality, Gram-Schmidt orthonormalisation, Expansion of an arbitrary vector, Basis-independence of the inner product, The Cauchy-Schwarz inequality
Matrices: Pauli matrices, Expansion of a (2x2) matrix, the exponential of a matrix, Rotation matrices in three dimensions: generators of infinitesimal rotations and their algebra, matrices as operators in a linear space, projection operators, Hermitian, unitary and positive definite matrices.
Infinite-dimensional vectors spaces: square-summable sequences, square-integrable functions, continuous basis, wave function of a particle, Hilber space, subspaces, linear manifolds.
Linear operators on a vector space: linear operators, norm and bounded operators, adjoint of an operator, derivative operator in square integrable space, adjoint of the derivative operator, nonsymmetric operators, matrix representations of unbounded operators. Useful operator identities: Hadamard's Lemma, Zassenhaus formula, Baker- Campbell-Hausdorff formula.
Orthogonal polynomials: Orthogonality and completeness, recursion relation, the classical orthogonal polynomials, hypergeometric differential equation, Rodrigues formula and generating function, Hermite polynomials, linear harmonic oscillator eigenfunctions, generalized Laguerre polynomials, Jacobi polynomials:Chebyshev polynomials and Legendre polynomials, associated Legendre functions, Spherical harmonics,
Discrete probability distributions, mean and variance, Bernoulii trials and the binomial distribution, number fluctuation in a classical ideal gas, the geometric distribution, photon number distribution in blackbody radiation, The Poisson distribution, Photon number distribution in coherent radiation, The sum of Poisson-distributed random variables, The simple random walk
Continuous probability distributions: Probability density and cumulative distribution, The moment-generating function, the cummulant-generating function, The Gaussian distribution, The Gaussian as a limit law, The central limit theorem.
Group Theory: Definitions and examples, discrete groups, cyclic groups, Subgroups, Cosets, Lie groups, Lie algebra and applications. Angular momentum operators, representation of rotations by SU(2) matrices, Connection between the groups SO(3) and SU(2), The parameter spaces of SU(2), SO(2) and SO(3). Isomorphism between SO(2) and U(1), The squeezing operator and the group SU(1,1), SU (1,1) generators in terms of Pauli matrices.

Text Books

1. Mathematical Physics with Applications, Problems, & Solutions, V. Balakrishnan, Ane Books Pvt. Ltd, 2018

References

2. Mathematics for physicists, P. Dennery and A. Krzywicki, Dover Publications, 2012
3. Vector and Tensor Analysis with Applications, A. I. Borisenko, Dover Publications, 1979
4. Group Theory and its application to physical problems, M. Hamermesh, Dover Publications
5. Introduction to Mathematical physics, Charlie Harper, Prentice Hall India Learning Private Limited, 1978
6. Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber and F. E. Harris, Elsevier, 2012

AV211 Analog Electronic Circuits (3 – 0 – 0) 3 credits

Basic stability and device stabilization techniques (BJT). Small signal low & high frequency models for (BJT, FET, MOSFET), Large signal amplifiers, Differential Amplifier, Instrumental amplifiers, Integrated circuits, Tuned amplifiers, Feedback amplifiers, Oscillators, Multivibrators, Wave shaping circuits, Filter design.
Basic stability and device stabilization techniques (BJT). Small signal low & high frequency models for (BJT, FET, MOSFET). Large signal amplifiers - Multistage amplifiers - Differential amplifier - Tuned amplifiers - Feedback amplifiers – Power amplifiers - Instrumental amplifiers. Oscillators – Multivibrator - Wave shaping circuits - Active Filter design- Integrated circuits (PLL, Timers, A/D converters)
.

Textbooks:

1. J. Millman and C.C. Halkias, Integrated Electronics - Analog and Digital circuit system, McGraw Hill, 1996.

References:

1. David A.Bell, Electronic Devices and Circuits, Prentice Hall of India, 2006.
2. Donal L. Schilling and Charles Beloue, Electronic Circuits , Third Edition, McGraw Hill, 2005.
3. David A. Bell, Solid State Pulse Circuits , Prentice Hall of India, 1992.
4. John D. Ryder, Electronic Fundamental and Applications - Integrated and Discrete system , Prentice Hall of India, 1999.
5. J. Millman and H. Taub, Pulse Digital and Switching waveform-Devices and circuits , McGraw

PH213 Classical Mechanics (3 – 1 – 0) 4 credits

Brief survey of the Newtonian mechanics of a particle and systems of particles; Constraints , generalised coordinates, D'Alembert's principle and Lagrange's equation, velocity dependent potential and dissipation function.

Variational principles and Lagrange's equations, Lagrange multipliers,conservation theorems and symmetry properties.

Central force motion, Kepler's laws,orbital dynamics, stability of circular orbits, precession of equinoxes and of satellite orbits.

Rigid body motion, Euler angles, inertia tensor and moment of inertia.

Euler's equations of motion, free motion of rigid bodies, motion of symmetric top.

Hamiltonian's canonical equations of motion,Routh's procedure; Principle of least action; Small oscillations, normal coordinates and normal mode frequencies.

Canonical transformations, equations of canonical transformations, symplectic approach.

Poisson Brackets (PB) and canonical invariants , infinitesimal canonical transformations, Noether's theorem conservation laws in the PB formulation, angular momentum PB relations.

Hamiltonian-Jacobi theory of linear oscillatory systems, Hamiltonian's principal and characteristic functions, separation of variables, action-angle variables;

Hamilton-Jacobi theory,geometrical optics and wave mechanics.

Text Books

1. Goldstein, H - Classical Mechanics, Addison Wesley, 2nd ed., 1980.
2. Biswas, S. N - Classical Mechanics, Books and Allied, 1998.

References

1. Rana, N. C and P. S. Jog - Classical Mechanics, Tata McGraw Hill, 1991.
2. Arnold,V. I - Mathematical Methods of Classical Mechanics, Springer Verlag, 1981.
3. Hand, L. N and J. D. Finch - Analytical Mechanics, Cambridge University Press, 1998.
4. L. Breklhovskikh, L and V. Gancharov - Mechanics of Continua and Wave dynamics, Springer Verlag, 1985.
5. Lai, W. M, D. Rubin and E. Krempl - Introduction to Continuum Mechanics, Pergamon Press, 1978.
6. Sommerfeld, A - Mechanics Academic Press, 1952.
7. Percival, I and S. Richards - Introduction to Dynamics Cambridge University Press, 1982.
8. Landau, L. D and E. M. Lifshitz - Mechanics, Pergamon Press, 1960.

HS211 Introduction to Economics (2 – 0 – 0) 2 credits

7. B.P. Lathi, Signal Processing and Linear Systems, Oxford University Press, 1998

Module 1: *Exploring the subject matter of Economics*

What is Economics? Definitions – Importance of Economics for Engineers – Schools of thought The Economic Problem – Scarcity and Choice – Resource allocation – the question of What to produce, How to Produce and How to Distribute Output – its nature and Importance in developing countries – Economic Systems – Basics of Capitalism, Socialism, Mixed Economy, Market Economy and Third World Economies.

Is Economics a Science? Distinction between Micro and Macro Economics.

Module 2: *Principles and Concepts of Micro Economics*

Determinants of individual demand/supply, Demand/Supply schedule and demand/supply curve, Market versus individual demand/supply, Shifts in the demand/supply curve, Demand and Supply together, How Prices allocate resources - Equilibrium - Elasticity - Consumer equilibrium – Marginal utility – Consumer surplus - Production – factors of production, production function – Laws – TR, AR, MR- Costs – TC, AC, MC, OC – Variable Vs Fixed costs – Short Run Vs Long Run costs - Markets – Perfect competition, Monopoly, Monopsony, Oligopoly.

Module 3: *Basics of Macro Economics*

The roots of macroeconomics, macroeconomic concerns, the role of government in the Macro economy, the components of the macro economy, the methodology of macroeconomics. Concepts of GNP, GDP, NNP, NDP and National Income – Personal Income and Disposable Income – Nominal and Real GDP – Limitations – Black Economy Concept of Inflation, Deflation, Methods of calculation – Classical Vs Keynesian Economics – Full employment Vs Under employment equilibrium – Globalization – Global Financial Crisis.

Module 4: *Economic Problems and Policies*

Developing Countries Vs Developed Countries, differences, characteristics, LDC's. Meaning of Development – Development Vs Growth, Measuring development - Problems of Growth – lessons and controversies, Indian situation - Poverty and Inequality – vicious circle of poverty – Recent BPL controversy - Population and Development – Demographic transition theory – optimum population - Agriculture, Industry and development - Balance of Payments – Closed and Open Economy – LPG- Planning and Growth – Global Financial Crisis.

A Research

Report. Text Books

1. Samuelson, Paul A and William D Nordhaus "Economics" (17^{th} Edition), Mc Graw Hill.
2. Dewett K K "Modern Economic Theory" S Chand
3. Thirlwall, A P "Growth and Development with Special Reference to Developing Economies" Palgrave.

References

1. Ackley, Gardner "Macroeconomic Theory" Surjeet Publications

2. Koutsoyiannis, A “Modern Micro Economics” Palgrave Macmillan
3. Black, John “Dictionary of Economics” Oxford University Press.
4. Meir, Jerald M and James E Rauch, “Leading Issues in Economic Development” (7th Edition) Oxford University Press.
5. Todaro, Michael P and Steven C Smith “Economic Development” Pearson Education Ltd.
6. Govt. of India, “Economic Survey” (latest survey) Ministry of Finance.
7. The Hindu, News paper, Daily.
8. Connor, David E “The Basics of Economics” Greenwood Press.

PH231 Optics Lab I (0 – 0 – 3) 1 credit

- ☐ Liquid lens
- ☐ Diffraction –single slit and circular aperture
- ☐ Michelson interferometer
- ☐ Faraday optic effect
- ☐ Beam profile of a laser diode
- ☐ Fabry-Perot etalon
- ☐ Rayleigh scattering
- ☐ Diffraction – wavelength of a He-Ne laser
- ☐ Birefringence

Text Books

Lab Manual

Semester – IV

MA221 Integral Transforms, PDE, and Calculus of Variations (3 – 0 – 0) 3 credits

Integral Transforms: The Fourier transform pair – algebraic properties of Fourier transform – convolution, modulation, and translation – transforms of derivatives and derivatives of transform – inversion theory. Laplace transforms of elementary functions – inverse Laplace transforms – linearity property – first and second shifting theorem – Laplace transforms of derivatives and integrals – Laplace transform of Dirac delta function – applications of Laplace transform in solving ordinary differential equations.

Partial Differential Equations: introduction to PDEs – modeling Problems related and general second order PDE – classification of PDE: hyperbolic, elliptic and parabolic PDEs – canonical form – scalar first order PDEs – method of characteristics – Charpits method – quasi- linear first order equations – shocks and rarefactions – solution of heat, wave, and Laplace equations using separable variable techniques and Fourier series.

Calculus of Variations: optimization of functional – Euler- Lagranges equations – first variation – isoperimetric problems – Rayleigh- Ritz method.

Text Books

1. Kreyszig, E., Advanced Engineering Mathematics, 10th ed., John Wiley (2011).

References

1. Wylie, C. R. and Barrett, L. C., Advanced Engineering Mathematics, McGraw- Hill (2002).
2. Greenberg, M. D., Advanced Engineering Mathematics, Pearson Education (2007).
3. James, G., Advanced Modern Engineering Mathematics, Pearson Education (2004).
4. Sneddon, I. N., Elements of Partial Differential Equations, McGraw- Hill (1986).
5. Renardy, M. and Rogers, R. C., An Introduction to Partial Differential Equations, 2nd ed., Springer-Verlag (2004).
6. McOwen, R. C., Partial Differential Equations - Methods and Applications, 2nd ed., Pearson Education (2003).
7. Borelli, R. L., Differential Equations: A Modelling Perspective, 2nd ed., Wiley (2004)

PH221 Modern Optics (3 – 0 – 0) 3 credits

Ray methods in optics, Fermats principle,ray transfer matrices(ABCD),unit planes, nodal planes, system of lens and mirrors. Ray methods in media with spatially varying refractive index. Aberrations, coma, astigmatism, curvature, distortion and chromatic aberration. (8 lectures)

Interference of light waves Two wave interference : By division of wavefront, division of amplitude, testing flatness of surfaces,interference with extended sources, Haidinger fringes, Fizeau fringes, Newton'sRings,Straightfringes, Two wave interferometers : Michelson Interferometer-temporal coherence. Twyman-Green Interferometer, Mach-Zehnder Interferometer, Sagnac Interferometer, Multiple beam interferometer :Fabry-Perot Interferometer. (10 lectures)

Diffraction Huygens Principle. Fresnel and Fraunhoffer diffraction, diffraction by single slit, graphical treatment of amplitudes, rectangular aperture, resolving power with rectangular aperture and resolving power of a prism, circular aperture and resolving powers of telescope and microscope, Double slit : qualitative aspects, derivation of equation of intensity, comparison of single and double slit patterns, position of maxima and minima, effect of finite width of slit, spatial coherence. Diffraction grating : principle, intensity distribution, maxima, minima, secondary maxima, spectra formation etc. Action of thin lens. Ultrasonic diffraction. Michelsons stellar interferometer, correlation interferometer. (12 lectures)

Polarization by reflection, polarization angle and Brewster's law, Malu's law, polarization by double refraction, Nicol Prizm, parallel and crossed polarizers, Wave plates, refraction by calcite prisms, Rochon and Wollaston prism, Polarization by scattering, Poincare sphere. Kerr, Pockels, and Faraday effects. (10 lectures)

Light quanta and their origin, thermal equilibrium of radiation, Einstein's coefficients, metastable states, population inversion, spontaneous and stimulated emission, Lasers, threshold for lasing,resonant cavities, two and three level lasers - examples. (6 lectures)

References:

1. Optics, by K K Sharma, Academic Press, 2006

2. Fundamentals of optics (4th Edition) Jenkins and White, McGraw Hill

3. Optics, by Ajoy Ghatak.

4. Born. M and E. Wolf, Principles of Optics, Seventh edition, Cambridge University Press, 2006.

5. Baha E. A., Saleh and M. C. Teich - Fundamentals of Photonics, John Wiley and Sons, 1991.

6. Goodman, J. W - Introduction to Fourier Optics, Third Edition, Viva Books Private Limited, 2007.

7. Basics of Laser Physics, K. F. Renk, Springer.

PH222 Quantum Mechanics (3 – 1 – 0) 4 credits

Mathematical Introduction: Linear vector spaces, inner products, linear operators, eigenvalue problem, generalization to infinite dimensions.

Towards quantum mechanics: relevant experiments, wave particle duality, uncertainty principle, postulates of quantum mechanics, Schrodinger equation, probability current and conservation.

Simple one-dimensional potential problems: Free particle, particle in a box; scattering in step-potentials, transmission and reflection coefficients.

Harmonic oscillator: Obtaining eigenvalues and eigen functions using ladder operators.

Angular momentum: Rotations in three dimensions, eigenvalue problem of L^2 and L_z.

Hydrogen atom: Eigenvalue problem, degeneracy of the spectrum, numerical estimates and comparison with experiments.

Text Books

1. R. Shankar, Principles of Quantum Mechanics, 2nd edition, Springer.
2. N. Zettili, Quantum Mechanics: Concepts and Applications, Wiley.

AE225 Fluid Dynamics (3 – 0 – 0) 3 credits

Fluid properties – fluid statics – fluid kinematics: material derivative, rotation, deformation – Reynolds transport theorem – physical conservation laws – integral and differential formulations – Navier-Stokes and energy equations – exact solution of Navier-Stokes equations: steady and unsteady flows – potential flows: basic flow patterns, superposition – waves in fluids – boundary layer theory: momentum integral approach, Blasius solution – introduction to turbulence.

Text Books

1. Kundu, P. K., Cohen, I. M., and Dowling. D. R., Fluid Mechanics, 5th ed., Academic Press (2012).

References

1. White, F. M., Fluid Mechanics, 7th ed., McGraw-Hill (2011).
2. Munson, B. R., D. F. Young, T. H. Okiishi, and W. W. Huebsch, Fundamentals of Fluid Mechanics, 6 th ed., John Wiley (2009).
3. Panton, R. L., Incompressible Flow, 3rd ed., John Wiley (2005).
4. Leal, L. G., Advanced Transport Phenomena, Cambridge Univ. Press (2007).

Hill International, 1965.

AV223 Signals and Systems (3 – 1 – 0) 4 credits

Classification of signals and systems, Types of signals, Transformation of independent variable, Periodic signals and Periodicity, Types of systems, Analysis of Continuous Time Signals and LTI systems: Convolution, Impulse response, Trigonometric and exponential Fourier series, Eigen functions of LTI systems, Fourier Transform, Magnitude and Phase Spectra, Properties of Fourier Transform, Laplace Transform, Region of Convergence, Properties, Linear Constant coefficient Differential Equations, State Space Matrix for continuous time systems.
Anlaysis of Discrete Time Signals and LTI DT systems: Periodicity, Discrete Convolution, DFT, Properties, Z Transform, ROC, Properties, Difference Equations, State variable equation and matrix, some applications – signal processing, communication, control systems etc.

Textbooks:

1. R.F. Ziemer, W.H. Tranter and D.R. Fannin, Signals and Systems - Continuous and Discrete, Prentice Hall, 2006.
2. B.P. Lathi, Linear Systems and signals, 2nd edition, Oxford University Press, 1998.
3. Simon Haykin, Barry Van Veen, Signals and Systems, John Wiley and Sons (Asia) Private Limited, 2005.
4. A.V. Oppenheim, A.S. Willsky and I.T. Young, Signals and Systems, Prentice Hall, 2006.

References:

1. Douglas K. Lindner, Introduction to Signals and Systems, Mc-Graw Hill International,1999.
2. Robert A. Gabel, Richard A. Roberts, Signals and Linear Systems, John Wiley and Sons (SEA) Private Limited, 1995.
3. M. J. Roberts, Signals and Systems - Analysis using Transform methods and MATLAB, Tata McGraw Hill, 2003.
4. J. Nagrath, S. N. Sharan, R. Ranjan, S. Kumar, Signals and Systems, Tata McGraw Hill, New Delhi, 2001.
5. Ashok Ambardar, Analog and Digital Signal Processing, 2nd Ed., Brooks/ Cole Publishing Company, 2006.

7. A. Papoulis, Circuits and Systems: A Modern Approach, HRW, 1980.

AV227 Instrumentation and Measurement (3 – 0 – 0) 3 credits

Introduction to measurement and instrumentation, Static characteristics of instruments; Types of Errors, Statistical Error Analysis, Propagation of Errors; Dynamic Characteristics of Instrumentation Systems, Sensor Reliability; Basic analog measuring instruments (PMMC, electrodynamometer, rectifier) and its use as electronic voltmeter and ammeter. Wattmeter and Energy meters; High Current/Voltage Measurement – C. T., P. T., C. V. T; Null-Based Measurement - D.C. and A.C. potentiometer, Wheatstone bridge circuits, Low and High resistance Measurement, Bridges for measurement of inductance and capacitance, Wagner-Earth connection; Typical Circuits in Measurement - Differential and Instrumentation Amplifier, Filters, Current Sources, Precision Rectifiers, V-to-f converters; Digital Measurement systems: Frequency and time-periodmeters, phase-angle measurement; Digital voltage measurement, DMM, Sample & Hold Circuits, A/D converters and comparative study, D/A circuits; General Instruments – CRO, DSO and Probes, Function Generator,Spectrum analyzers, Data Acquisition Systems; Transducers & Signal Conditioning: Resistive Sensors (Potentiometers, Strain gauges and Load Cell, Torsion Bars, RTD, Thermistor); Inductive transducers (Variable Reluctance sensors, LVDT, Tachogenerator) and Capacitive transducers; Temperature sensors (Thermocouple, Semiconductor), Light Sensing Devices, Piezoelectric sensors, Pressure Sensors

Text Books:

1. Doebelin, E.O., Measurement systems: Application and Design, 5th ed., McGraw hill, 2003.
2. Albert D. Helfrick, William D. Cooper, Modern Electronic Instrumentation and Measurement Techniques, Prentice Hall of India Private Limited.

References:

1. J. G. Webster, The Measurement, Instrumentation and Sensors Handbook, Vol 1 and 2, CRC Press, 1999
2. Golding E.W. and Widdis F.E., Electrical measurements and measuring instruments, Sir Issac Pitman and Sons pvt ltd, 1995.
3. 3.John P. Bentley, Principle of Measurement Systems, Pearson Education; 3rd Edition, 2006.
4. L. K. Baxter,Capacitive Sensors – Design and Applications, IEEE Press Series on Electronic Technology, NJ (1997).

1. M. B. Stout,Basic Electrical Measurements, Prentice Hall Pvt. Ltd., India, New Delhi, 1982.

HS221 Introduction to Social Science and Ethics (2 – 0 – 0) 2 credits

Social Science: introduction to sociology, anthropology – social science research design and sampling.

Ethics: professional and personal ethics – values & norms and human rights.

Text Books

- Lecture Notes

References

2. Perry, J. and Perry, E., Contemporary Society: An Introduction to Social Science, 11th ed., Allyn & Bacon (2005).
3. Giddens, A., Sociology, 5th ed., Wiley (2006).
4. Flyvbjerg, B., Making Social Science Matter, Cambridge Univ. Press (2001).
5. Singer, P., A Companion to Ethics, Wiley-Blackwell (1993).

PH241 Optics Lab II (0 – 0 – 3) 1 credit

- Stokes parameter
- Diffraction at an edge

- ☐ Fourier optics
- ☐ Fiber optics-numerical aperture and fiber loss
- ☐ Measurement of refractive index and absorption coefficient
- ☐ Characterization of optical sources – LED and Laser diode
- ☐ Pockel effect
- ☐ Kerr effect
- ☐ Ultrasonic diffraction
- ☐ Holography

Text Books

Lab Manual

Semester – V

MA311 Probability, Statistics, and Numerical Methods (3 – 0 – 0) 3 credits

Probability Theory: Elementary concepts on probability – axiomatic definition of probability – conditional probability – Bayes' theorem – random variables – standard discrete and continuous distributions – moments of random variables – moment generating functions – multivariate random variables – joint distributions of random variables – conditional and marginal distributions – conditional expectation – distributions of functions of random variables – *t* and χ^2 distributions – Schwartz and Chebyshev inequalities – weak law of large numbers for finite variance case – central limit theorem for iid finite variance case.

Statistics: Elementary concepts on populations, samples, statistics – sampling distributions of sample mean and sample variance – point estimators and its important properties – point estimator for mean and variance and proportion – confidence interval for sample mean – tests of hypotheses – Chi-squared test of goodness of fit.

Numerical Methods: Solution of algebraic and transcendental equations – system of linear algebraic equations – interpolation – numerical integration – numerical solution of ordinary differential equations – system of nonlinear algebraic equations.

Text Books

1. Walpole, W. E., Myers, R. H., Myers, S. L., and Ye, K., Probability & Statistics for Engineers & Scientists, 9th ed., Pearson Education (2012).
2. Jain, M. K., Iyengar, S. R. K., and Jain, R. K., Numerical Methods for Scientific and Engi-neering Computation, New Age International (2003).

References

1. Johnson, R. A., Miller & Freund's Probability and Statistics for Engineers, 6th ed., Prentice Hall (2000).
2. Milton, J. S. and Arnold, J. C., Introduction to Probability and Statistics: Principles and Applications for Engineering and the Computing Sciences, McGraw- Hill (2002).
3. Ross, S. M., Introduction to Probability and Statistics for Engineers and Scientists, 3 rd ed., Academic Press (2004).
4. Hogg, R. V. and Tanis, E. A., Probability and Statistical Inference, 7th ed., Prentice Hall (2005).
5. Larsen, R. J. and Marx, M. L., An Introduction to Mathematical Statistics and its Applications, 4th ed., Prentice Hall (2005).
6. Conte, S. D. and de Boor, C., Elementary Numerical Analysis, 3rd ed., Tata McGraw-Hill(2005).
7. Krishnamurthy, K. V., Numerical Algorithms, Affiliated East-West Press (1986).

PH311 Atomic and molecular spectroscopy (3 – 1 – 0) 4 credits

Spectra of alkali atoms, vector atom model, LS and JJ couplings, doublet fine structure, two electron atom, Zeeman and Paschen-Back effect, normal and anomalous Zeeman effect, Stark effect.

Symmetric and antisymmetric wave functions, Slater determinants, constant field approximation, Hartree-Fock method, Born-Oppenheimer approximation.

Fine structure of spectral lines, nuclear spin and hyperfine structure, spectra of diatomic molecules, polyatomic molecules.

X-ray spectra, general factors influencing spectral line widths and line intensities, molecular symmetry, irreducible representation, rotational and vibrational spectra of diatomic molecules, Electronic spectra, Franck-Condon principle, bond dissociation energies, molecular orbitals and models, fluorescence and phosphorescence.

FTIR and Laser Raman spectroscopy, magnetic resonance, ESR and MNR spectra, lasers, interaction of laser with atoms.

Absorption, emission and scattering of radiation, optical Bloch equations, optical pumping, coherent interaction of light with atoms, atomic coherence, Hanle effect, coherent population trapping, electromagnetically induced transparency.

PH312 Statistical Mechanics (3 – 0 – 0) 3 credits

Preliminary concepts, probability theory, introduction to central limit theorem, random walk problem, quasi-static process,thermal and mechanical interactions, laws of thermodynamics, thermodynamic potentials.

Statistical description of a system of particles,microstates, concept of ensembles, basic postulates, phase space, Liouville's theorem, microcanonical, canonical and grand canonical ensembles. Partition functions. Chemical potential,free energy and connection with thermodynamic variables. Equivalence of ensembles. Ideal gas,Gibbs paradox, M-B gas velocity distribution. Equipartition theorem,

Formulation of quantum statistics,density matrix, ensembles in quantum statistical mechanics. Identical particles, Maxwell-Boltzmann,Bose-Einstein and Fermi-Dirac statistics. Black body radiation,Stefan-Boltzmann law, Wien's displacement law, Einstein and Debye’s theories of specific heat of solids. Ideal Bose gas, Bose-Einstein condensation, Ideal Fermi gas.Ideal gases in the classical limit.

Introduction to first and second order phase transitions.

Text books:

1. Stat. Mech. by R. K. Pathria and P. D. Beale
2. Stat. Mech. by K. Huang

AE315 Thermodynamics (3 – 0 – 0) 3 credits

Thermodynamic system and state variables; properties of pure substances; equation of state, law of corresponding states; first law and its consequences, reversible, irreversible and quasi-static processes; second law: heat engines, concept of entropy and its statistical interpretation, entropy balance, maximum entropy and minimum energy; Maxwell’s relations, evaluation of thermodynamic properties; thermodynamic properties of gas mixtures.

Textbook

1. Borgnakke, C. and R. E. Sonntag, Fundamentals of Thermodynamics, 7th ed., John Wiley (2009).

References

1. Zemansky, M. W. and R. H. Dittman, Heat and thermodynamics, 7th ed., McGraw-Hill (1997).
2. Balmer, R. T., Modern Engineering Thermodynamics, Academic Press (2010).
3. Moran, M. J., Shapiro, H. N., Boettner, D. D., and Bailey, M. B., Principles of Engineering Thermodynamics (SI Version), 8th ed., Wiley (2015).
4. Cengel, Y. A. and Boles, M. A., Thermodynamics: An Engineering Approach, 8th ed., McGraw-Hill (2014).
5. Annamalai, K., I. K. Puri, and M. A. Jog, Advanced Thermodynamics Engineering, CRC Press (2010).

HS311 Principles of Management Systems (3 – 0 – 0) 3 credits

Industrial Management: Development of Management thought-Management Functions – planning – organizing – power and authority-organization structures – span of control – delegation, leadership, directing and controlling-management by objectives-forecasting models.

Project Management: Characteristics of R&D projects – Development of project network – project representation – project scheduling – linear time – cost trade-offs in projects-project monitoring and control with PERT – resource leveling-break even analysis – application of linear programming in resource allocations-simplex method.

Human Resource Management: personnel management-functions of HRM – assignment of people to projects-man power planning-workers participation in management – grievance handling – performance appraisal – organizing for maximum performance: quality of work life, job rotation, job enrichment.

Text Books/References

1. Koontz H., O Donnel, C., and Weihrich, H., Essentials of Management, McGraw-Hill (1990).
2. Venkataratnam, C. S. and Srivastava, B. K., Personnel Management and Human Resources, Tata McGraw-Hill (1991).
3. Mazda F., Engineering Management, Prentice Hall (1997).
4. Gido, J. and Clements, J. P., Successful Project Management, 2nd ed., South-Western College Publishing (2003).
5. Khanna, O. P., Industrial Engineering and Management, Dhanpat Rai Publications (P) Ltd. (2003).
6. Memoria, C. B. and Gankar, S. V., Personnel Management – Text and Cases, Himalaya Publishing House (2007).

PH331 Modern Physics Lab (0 – 0 – 6) 2 credit

- ☐ Law of distance and absorption of gama or beta rays using Geiger-Muller counter
- ☐ Zeeman effect
- ☐ Fine structure effect
- ☐ One electron and two electron spectra
- ☐ Atomic spectra of two electron systems
- ☐ Balmer series: determination of Rydberg's constant
- ☐ Magnetostriction measurement with Michelson interferometer

- ☐ Statistical analysis of data using charging and discharging of a capacitor
- ☐ X-ray fluorescence
- ☐ Moseley's law using NaI(Ti) scintillator detector
- ☐ Gamma ray spectroscopy
- ☐ Fourier series

AV337 Instrumentation and Measurement Lab (0 – 0 – 3) 1 credit

- ☐ Resistance measurement through Wheatstone bridge
  - DC excitation
  - AC excitation
- ☐ Measurement of capacitance
  - Wein bridge
  - Schering bridge
  - Small variation in capacitance
- ☐ Inductive transducers
  - Inductance measurement
  - LVDT
- ☐ Variable resistivity transducers
  - Strain guage
  - Resistance of a salt solution
  - Variable area transducer
- ☐ Measurement of temperature
  - Thermocouple
  - Thermistor
  - RTD
- ☐ Light detector
  - Photo resistor
  - Photo transistor
  - Photo diode
- ☐ Calibration of flow and level
- ☐ Calibration of Value and pressure gauges
- ☐ Dead weight tester for pressure calibration
- ☐ PC based temperature calibrator
  -

Semester – VI

PH321 Introduction to Solid State Physics (3 – 0 – 0) 3 credits

Bonding in Condensed matter Physics: Forces and energy of interatomic bonding, Primary bonds: Covalent bonds, Ionic bonds, Metallic bonds etc. Secondary bonds: Van der Waals bonds, Hydrogen bonds etc.

Crystal structure: Bravais lattice, primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; Common crystal structures; Reciprocal lattice and Brillouin zone; Bragg-Laue formulation of X-ray diffraction by a crystal.

Band theory of solids: Free electron theory, Limitations of free electron theory; Periodic potential and Bloch's theorem; Nearly free electron model; origin of Bands and band gaps; Tight binding method; Effective mass of an electron in a band: concept of holes; Energy band in one dimension, different zone schemes; E-k diagram in three dimensions, band structures and energy gap; Classification of metal, semiconductor and insulator; Fermi energy, Topology of Fermi surfaces.

Lattice dynamics and Specific heat: Classical theory of lattice vibration under harmonic approximation; Vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limits; Normal modes and phonons; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity.

Magnetic properties of solids: Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: quantum theory of paramagnetism; Mean field theory: Ferromagnetism, Curie-Weiss law, temperature dependence of saturated magnetisation, ferromagnetic domains; Heisenberg model (introduction) Ferrimagnetism and antiferromagnetism.

Superconductivity: Overview of superconductivity - Experimental survey; Zero resistance state, Meissner effect, flux quantization, London equations, penetration depth, isotope effect, specific heat. Type I and Type II superconductors. Electron-electron interaction via lattice: Cooper pairs and BCS formalism, multiband, High Tc superconductors (qualitative discussion).

Text books:

1. Ali Omar, Elementary Solid State Physics, Pearson
2. N. Ashcroft and D. Mermin, Solid State Physics, Cengage.
3. Charles Kittel, Introduction to Solid State Physics, Wiley.
4. H. Ibach and H. Luth, Solid State Physics: An Introduction to Theory and Experiment, Springer.
5. A. C. Rose-Innes and E. H. Rhoderick, Introduction to Superconductivity, Pergamon.

ES322 Introduction to Earth, Atmosphere and Ocean Sciences (3 – 0 – 0) 3 credits

Atmospheric Science:

General introduction – Structure of the Atmosphere, Composition of Atmosphere.

Radiative processes – Black body radiation – Scattering & Absorption – Greenhouse effect.

Hydrostatic equation – First Law of Thermodynamics – Adiabatic processes – Dry & Moist air – Virtual temperature – Convection.

Clouds – Growth of clouds droplets to rain.

Frames of references – Fundamental forces – Equations governing conservation of mass, momentum, energy – Coriolis force.

Horizontal motion in the atmosphere – Scale analysis – Geostropic wind – Gradient wind.

General circulation – Jet streams – ITCZ – Monsoons.

Ocean:

General introduction - Physical characteristics of Ocean – The Ocean basins.

Density of sea water, distribution of temperature, salinity and density in space & time.

Heat budget of the Ocean.

Ocean circulation – The wind driven circulation – Ekman layer.

Western boundary currents – Sverdrup theory.

Thermohaline circulation.

Air sea interactions.

Wind-forced circulation of the Indian Ocean.

Solid Earth:

Earth's origin and composition.

Earth's interior and exploring its dynamic interaction with the surface.

Plate tectonics as the driving force for volcanism, mountain building, and earthquakes.

Minerals, ores and rocks: formation processes, general physical and chemical properties.

Petroleum, coal and natural gas – origin, structure and composition, accumulation/migration, source/reservoir rocks.

Text Books/References:

1. An introductory Survey, 2^{nd} Edition by J.M. Wallace and P.V. Hobbs, Academic Press
2. Introduction to Physical Oceanography, Robert H Stewart
3. Engineering and general geology by Parbin Singh

ES323 Astrophysical Concepts (3 – 0 – 0) 3 credits

Sky coordinates and motions: Earth Rotation – Sky coordinates – seasons – phases of the Moon – the Moon's orbit and eclipses – timekeeping (sidereal vs synodic period).

Planetary motions – Kepler's Laws – Gravity.

Light & Energy – Telescopes – Optics –

Detectors.

Planets: Formation of Solar System – planet types – planet atmospheres – extrasolar planets.

Stars: Measuring stellar characteristics (temperature, distance, luminosity, mass, size) – HR diagram – stellar structure (equilibrium, nuclear reactions, energy transport) – stellar evolution.

Galaxies: Our Milky Way – Galactic structure – Galactic rotation – Galaxy types – Galaxy formation.

Cosmology: Expansion of the Universe – redshifts – supernovae – the Big Bang – history of the Universe – fate of the Universe.

Text Books/References:

1. B. W. Carroll & D. A. Ostlie, An Introduction to Modern Astrophysics, Latest Edition, Addison-Wesley.
2. Frank Shu, The Physical Universe, Latest Edition, University Science Books.
3. Martin Harwit, Astrophysical Concepts, Latest Edition, Springer.
4. T. Padmanabhan, Invitation to Astrophysics, Latest Edition, World Scientific Publishing Co.
5. T. Padmanabhan, Theoretical Astrophysics vols 1-3, Latest Edition, Cambridge University Press.
6. Malcolm Longair, High Energy Astrophysics, vols 1-2, Latest Edition, Cambridge University Press.
7. Sparke and Gallaghar, Galaxies in the Universe: An Introduction, Latest Edition, Cambridge University Press.
8. Dina Prialnik: An Introduction to the Theory of Stellar Structure and Evolution, Latest Edition, Cambridge University Press.

HS321 Environmental Science and Engineering (3 – 0 – 0) 3 credits

Awareness of the impact of environment on quality of life – natural resources – biological systems – bio-geo chemical cycles – chemical processes; water treatment operations, water sampling, storage, quality measurement – oxygen demand – detection of pollutants – current environmental issues; pollutants, global warming, causes and consequences, air pollution,organic and inorganic air pollutants, smog- acid mine drainage, accumulation of salts in water– soil formation; micro and macro nutrients in soil, pollutants in soil – green chemistry: an alternative tool for reducing pollution – engineering interventions; flow sheets, waste minimization, e- waste management, ASP, reverse osmosis, trickling filter – environmental management; solid, liquid waste management, hazardous wastes, ISO standards – Kyoto protocol, Montreal protocol, Euro norms.

Text Books

1. Rao, V., Textbook of Environmental Engineering, Prentice Hall of India (2002).

References

1. Baird, C. and Cann, M., Environmental Chemistry, 3rd ed., W. H. Freeman and Company (2005).
2. Manual on Water Supply and Treatment, CPHEEO, Ministry of Urban Development, GOI (1999).
3. Manual on Sewerage and Sewage Development, CPHEEO, Ministry of Urban Development, GOI (1993).
4. Hauser, B. A., Practical Hydraulics Hand Book, Lewis Publishers (1991).
5. Hammer, M. J., Water and Wastewater Technology, Regents/Prentice Hall (1991).
6. Sharma, J. P., Comprehensive Environmental Studies, Laxmi Publications (2004).
7. Garg, S. K., Environmental Engineering (vol. 1 and 2), Khanna Publishers (2004).
8. Kiely, G., Environmental Engineering, McGraw- Hill (1997).
9. Bharucha, E., Textbook of Environmental Studies, University Grants Commission (2004).
10. Vanloon, G. W. and Duffy, S. J., Environmental Chemistry: A Global Perspective, Oxford Univ. Press (2000).

E01 Elective I (3 – 0 – 0) 3 credits

E02 Elective II (3 – 0 – 0) 3 credits

PH341 Solid State Physics Lab (0 – 0 – 1) 1 credit

- X-ray diffraction
- X-ray fluorescence
- Dielectric loss variation with frequency and temperature
- Curie temperature measurement
- Magnetic susceptibility by quink's tube
- Electrical conductivity by two probe and four probe
- NMR

- ☐ ESR
- ☐ Hall effect
- ☐ Band gap of LED using Newton's ring
- ☐ P-N junction characterization

Text Books

Lab Manual

PH351 Comprehensive Viva-Voce I (0 – 0 – 0) 3 credits

Elective I and II Courses

PH361 Quantum Information Theory (3 – 0 – 0) 3 credits

Quantum bits and quantum gates: quantum bits, basic computations with 1-qubit quantum gates, Pauli matrices or I, X, Y, Z-gates, Hadamard matrix gate or H-gate, quantum gates with multiple qubit inputs and outputs, quantum circuits, non cloning theorem.

Quantum measurements: quantum measurements and types, quantum measurements in the orthonormal basis, Projective or von-Neumann measurements, POVM measurements, quantum measurements on joint states.

Qubit measurements, superdense coding, and quantum teleportation: measuring single quits, measuring n-qubits, Bell state measurement, superdense coding, quantum teleportation, distributed quantum computing.

Deutch-Joza, quantum Fourier transform, and Grover quantum database search algorithms, Shor's factorisation algorithm.

Von Neumann entropy, Relative, joint, and conditional entropy, and mutual information, quantum communication channel and Holevo bound.

Quantum data compression and fidelity. Schumacher's quantum coding theorem, quantum Channel noise and channel capacity, Quantum error correction.

Quantum cryptography: Electromagnetic waves, polarization states, photons, and quantum measurements, the BB84 protocol, the B92 protocol, the EPR protocol.

Text Books/References

1. Classical and Quantum Information Theory: An Introduction for the Telecom Scientist, E Desurvire, Cambridge University Press
2. Quantum Computation and Quantum Information, Michael A. Nielsen & Isaac L. Chuang, Cambridge University Press

PH362 Non-linear Dynamics, Chaos and Fractals (3 – 0 – 0) 3 credits

Flows on the line: Introduction; Fixed points and stability; Population growth; Linear Stability Analysis; Existence and Uniqueness; Impossibility of oscillations; Potentials

Bifurcations: Saddle-node bifurcation; Transcritical bifurcation; Laser threshold; Pitchfork bifurcation; Overdamped bead on a rotating hoop; Imperfect bifurcations and catastrophes; Insect outbreak

Flows on a circle: Examples and Definitions; Uniform Oscillator; Nonuniform Oscillator; Overdamped Pendulum; Fireflies; Superconducting Josephson junctions

Linear Systems: Definitions and examples; Classification of linear systems; Love Affairs

Phase Plane: Phase portraits; Existence, uniqueness and topological consequences; Fixed points and linearization; Rabbits versus sheep; Conservative systems; Reversible systems; Pendulum

Limit Cycles: Examples; Ruling out closed orbits; Poincare-Bendixson theorem; Lienard systems

Bifurcations Revisited: Saddle-node, transcritical and pitchfork bifurcaations; Hopf bifurcations; Oscillating chemical reactions; Global bifurcations of cycles; Hysterisis in the driven pendulum and Josephson junction; Coupled oscillators and quasiperiodicity; Poincare maps

Lorenz equations: A chaotic waterwheel; Simple properties of the Lorenz equations; Chaos on a strange attractor; Lorenz map; Exploring parameter space

One-dimensional maps: Fixed points and cobwebs; Logistic map: Numerics and Analysis; Periodic windows;

Liapunov exponent; Universality and experiments

Fractals: Countable and Uncountable Sets; Cantor set; Dimension of self-similar fractals; Box dimension; Pointwise and correlation dimensions

Strange attractors: Examples; Henon map; Rossler system; Chemical chaos

Text Books/References

1. Nonlinear Dynamics and Chaos by Steven Strogagtz, Perseus Books

ES361 Introduction to Remote Sensing (3 – 0 – 0) 3 credits

Definition and overview of remote sensing, electromagnetic radiation and its interaction with matter, Spectral signatures of surface materials, physical basis of signatures, radiometric and geometric distortions and corrections, remote sensors and platforms – optical, infrared and microwave sensors, active remote sensing techniques: LIDAR and Microwave remote sensing, and radars, data formats, remote sensing data interpretation – visual and digital interpretation techniques, remote sensing applications.

Text Books/References

1. Introduction to Remote Sensing by James B. Campbell, 4th Edition, Guilford Press
2. Remote Sensing and Image Interpretation (5th Ed.) by Thomas M. Lillesand, and Ralph W. Kiefer, John Wiley & Sons Ltd.
3. Fundamentals of Remote Sensing by George Joseph,Universities Press
4. Remote Sensing: Optics and Optical Systems by Slater, P.N, Addison-Wesley Publishing

ES362 Geographic Information System (3 – 0 – 0) 3 credits

Introduction to Geographic Information System (GIS) – Hardware, Software, Data types and models – Spatial data quality, Thematic maps, Symbolization, Scale and generalization – Co-ordinate systems, Map projections and visualization – Input / output techniques in GIS (spatial and non-spatial), Editing, Topology, Database structure – Analysis: spatial, network analysis, optimization of path, time and cost, Routing and events, Facility location, Interpolation methods, Digital elevation model, Surface analysis – Geovisualization – Decision support systems, OpenGIS, WebGIS, Enterprise GIS – Planning, Designing and Implementation, National Spatial Data Infrastructure (NSDI), Future trends.

Text Books/References

1. Concepts and Techniques of Geographic Information Systems by Lo C.P. and Yeung A.K.W., (2nd Ed.), Prentice Hall, 2006.
2. Introduction to Geographic Information Systems by Kang-Tsung Chang, McGraw Hill Publishers.
3. Principles of Geographical Information Systems by Burrough P.A. and McDonnell R.A., Oxford University Press, 1998.
4. Geographic Information Systems and Science by Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, John Wiley & Sons Ltd.
5. The Handbook of Geographic Information Science, Wilson J. (Ed), Wiley-Blackwell, 2007.

MA361 Computer Modelling and Simulation (3 – 0 – 0) 3 credits

Meaning and importance of simulation and modelling, classification of models, Variables and problem formulation, performance measures, Data collection and analysis, SIMSCRIPT language concept: general syntax, Discrete event modelling, process and resources, timing and pending list, accumulate and tally, process instance and object oriented aspects, sets and data structures, Probability distribution, Random number and random variant generation. Input modelling and output analysis. Generation of graphical output, user interface and animation in SIMSCRIPT, development of simulation models of real system through integration of programming and statistical concepts, issues related to credibility of models.

Text Books/References

MA362 Optimization Techniques (3 – 0 – 0) 3 credits

Optimization: Need for unconstrained methods in solving constrained problems, Necessary conditions of unconstrained optimization, Structure methods, Quadratic models, Methods of line search, Steepest descent method, Quasi-Newton methods: DFP, BFGS, Conjugate-direction methods:, Methods for sums of squares and nonlinear equations ,Linear Programming: Simplex Methods, Duality ii LPP, Transportation problem, Nonlinear programming: Lagrange Multiplier, KKT conditions, Convex programming.

Text Books

1. E. K. Chong and S. H. Zak, An Introduction to Optimization, 2nd Ed., Wiley India, 2001.

References

1. D. G. Luenberger and Y. Ye, Linear and Nonlinear Programming, 3rd Ed., Springer India, 2008.
2. N. S. Kambo, Mathematical Programming Techniques, East-West Press, 1997.

MA363 Artificial Neural Networks (3 – 0 – 0) 3 credits

Foundations of Biological Neural Networks and Artificial Neural Networks (Learning, Generalization, Memory, Abstraction, Applications), McCulloch-Pitts Model, Historical Developments.ANN Architectures, Learning Strategy (Supervised, Unsupervised, Reinforcement), Applications: Function Approximation, Prediction, Optimization.

Associative Memories: Matrix memories, Bidirectional Associative Memory, Hopfield Neural Network. Neural Architectures with Unsupervised Learning: Competitive learning, Principal Component Analysis Networks (PCA), Kohonen's Self-Organizing Maps, Linear Vector Quantization, Adaptive Resonance Theory (ART) Networks, Independent Component Analysis Networks (ICA).

Text Books/References

AE361 Operations Research (3 – 0 – 0) 3 credits

Introduction – linear programming – duality and sensitivity analysis – transportation and assignment problems – integer programming – network optimization models – dynamic programming – non-linear programming – unconstrained and constrained optimization – non-traditional optimization algorithms.

Text Books

1. Ravindran, A., D. T. Philips, and J. J. Solberg, Operations Research: Principles and Practice, 2 nd ed., John Wiley, 2012.

References

1. Taha, H. A., Operations Research: An Introduction, 9th ed., PHI, 2010.
2. Winston, W. L., Operations Research: Applications and Algorithms, 4th ed., Cengage Learning, 2010.
3. Rao, S. S., Engineering Optimization – Theory and Practices, 4th ed., John Wiley, 2009.
4. Deb, K., Optimization for Engineering Design: Algorithms and Examples, 2nd ed., PHI, 2012.

AV489 PATTERN RECOGNITION AND MACHINE LEARNING (3-0-0) 3 Credits

PR overview-Feature extraction-Statistical Pattern Recognition-Supervised Learning-Parametric methods-Non parametric methods; ML estimation-Bayes estimation-k NN approaches. Dimensionality reduction, data normalization. Regression, and time series analysis. Linear discriminat functions. Fishers linear discriminant, linear perceptron and Neural Networks. Kernel methods and Support vector machine. Unsupervised learning and clustering. K-means and hierarchical clustering. Ensemble/ Adaboost classifier, Soft computing paradigms for classification and clustering. Applications to document analysis and recognition.

Text Books / References:

1. Pattern Classification (Pt.1) 2nd Edition by Richard O. Duda, Peter E. Hart, David G. Stork
2. "Pattern Recognition and Machine Learning", C.M. Bishop, 2nd Edition, Springer, 2011.
3. 3.Sergios Theodoridis, "Machine Learning: A Bayesian and Optimization Perspective". Elsevier, 2015.92

AV490 DEEP LEARNING FOR COMPUTATIONAL DATA SCIENCE (3-0-0) 3 Credits

Description: Deep learning methods are now prevalent in the area of machine learning, and are now used invariably in many research areas. In recent years it received significant media attention as well. The influx of research articles in this area demonstrates that these methods are remarkably successful at a diverse range of tasks. Namely self driving cars, new kinds of video games, AI, Automation, object detection and recognition, surveillance tracking etc.

The proposed course aims at introducing the foundations of Deep learning to various professionals who are working in the area of automation, machine learning, artificial intelligence, mathematics, statistics, and neurosciences (both theory and applications). This is proposed course to introduce Neural networks and Deep learning approaches (mainly Convolutional Neural networks) and give few typical applications, where and how they are applied. The following topics will be explored in the proposed course.
We will cover a range of topics from basic neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning, and applications to problem domains like speech recognition and computer vision.

Text Books/References:

1. Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classication. Wiley-Interscience. 2nd Edition. 2001.
2. Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008.
3. Russell, S. and Norvig, N. Articial Intelligence: A Modern Approach. Prentice Hall Series in Articial Intelligence. 2003.
4. Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995.
5. Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001.
6. Koller, D. and Friedman, N. Probabilistic Graphical Models. MIT Press. 2009.93

AV491 ADVANCED SENSOR AND INTERFACE ELECTRONICS (3-0-0) 3 Credits

Introduction and Background of state-of-art sensing and measurement techniques. Contactless potentiometer (resistance-capacitance scheme) – Methodology,Interface Circuits, Overview of Flight Instrumentation.
Analog Electronic Blocks, CMRR Analysis (Non-ideal opamps) of an Instrumentation Amplifier,
Linearization circuits for single-element wheatstone bridges (application to strain gauge), Direct Digital Converter for Strain gauges, Signal conditioning for Remote-connected sensor elements.
Inductive sensors and electronic circuits, Eddy-current based sensors, Synchros and Resolvers, Magnetic shielding techniques.

State-of-art Magnetic Sensors – Principle, Characteristics and Applications – Induction Magnetometer, Flux gate Magnetometer, Hall Effect Sensor, Magnetoresistance Sensors, GMR Sensors – Multi-layer and Spin Valve, Wiegand Effect, SQUID.
Case Study-1: GMR Based Angular Position Sensor, Sensing Arrangement, Linearization Electronics – Methodology, Circuit Design and Analysis.
Case study-2: Brake Wear Monitoring, Reluctance-Hall Effect Angle Transducer–Sensing arrangement,Front-end Electronics.Overview of Basic Capacitive sensors.Various design considerations; guarding, stray fields, offset and stray capacitance, Ratio metric measurement – advantages and circuit implementations. RMS, Peak, Average Value Electronic Schemes for Capacitive Sensors, Synchronous Phase Detection – multiplier and switching type.

Case study-3: Liquid level detection – Concentric Cylindrical Plates, Plates on container walls – Dielectric and Conductive Liquids - Analysis. Case study-4: Capacitive Angle Transducers and Front-end electronics.
Piezoelectric sensors, Seismic transducers. Introduction to MEMS, Piezoelectric, Electrodynamic and MEMS Capacitive Accelerometers, Principles of Ultrasonic sensors - Equivalent circuit and transfer function of a piezoelectric transmitter, crystal oscillator. NDT using ultrasonic and eddy-current. Optical and Fibre Optic Sensors
MEMS Pressure sensors, Vaccum-pressure estimation and important flow measurement (volume and mass flow rate) schemes, Flapper-nozzle systems. Sensing Schemes for Attitude, Position measurement and navigation, Instrumentation Systems for Occupancy Detection – Ultrasound, Inductive and Capacitive schemes. Non-contact current and voltage measurement, Newhuman vital-sign sensing techniques.

Text Books:
1. Ramón Pallás-Areny,John G. Webster, Sensors and Signal Conditioning, 2nd Edition, Wiley, 2003
2. Doebelin, E.O., Measurement systems: Application and Design, 5th ed., McGraw hill, 2003.94
References:
1. J. G. Webster, The Measurement, Instrumentation and Sensors Handbook, Vol 1 and 2, CRC Press, 1999
2. L. K. Baxter,Capacitive Sensors – Design and Applications,IEEE Press Series on Electronic Technology, NJ (1997)
3. Jacob Fraden, Handbook of Modern Sensors – Physics, Designs and Applications, Springer, 4th Edition, 2010
4. John P. Bentley, Principle of Measurement Systems, Pearson Education; 3rd Edition, 2006
5. A. Barua, Fundamentals of Industrial Instrumentation, Wiley, 201395

AV493 MACHINE LEARNING FOR SIGNAL PROCESSING (3-0-0) 3 Credits

Introduction: Representing text, Sounds and Images text, speech, image, and video. Signal processing for feature extraction: for Text (BoW), Speech (LPC, Mel-frequency Capstral coefficients, STFT and Wavelet features), Images (HoG, BoVW, FV), Videos (BoVW).
Machine Learning basics - Introduction to pattern recognition, Bayesian decision theory, supervised learning from data, parametric and non parametric estimation of density functions, Bayes and nearest neighbor classifiers, introduction to statistical learning theory, empirical risk minimization, discriminant functions, learning linear discriminant functions, Perceptron, linear least squares regression, LMS algorithm, Supervised and Unsupervised learning, Classification and Regression (linear models), Evaluation metrics, Probability Models and Expectation-Maximization Algorithm,
Gaussian Mixture Models, Neural Networks and Deep Learning, Multi-class classification and Multilabel classification, Different kinds of non-linearities, objective functions, and learning methods, ML for Audio Classification, Time Series Analysis, LSTMs, and CNNs, ML for Speech Recognition, Hidden Markov Models, Finite State Transducers and Dynamic Programming, ML for Music Information Retrieval, Latent Variable Models, Matrix Factorization and Signal Separation, ML for Image Processing, Transfer Learning, Attention models, Attribute-based learning, ML for Communication, Deep learning for wireless applications

Text books:
1. Pattern Classification (Pt.1) 2nd Edition, by Richard O. Duda (Author), Peter E. Hart (Author), David G. Stork (Author)

2. “Pattern Recognition and Machine Learning”, C.M. Bishop, 2nd Edition, Springer, 2011.
3. Sergios Theodoridis, "Machine Learning: A Bayesian and Optimization Perspective". Elsevier, 2015.

Refereces:

1. Deep Learning By Ian Goodfellow, Yoshua Bengio, Aaron Courville Online book, 2017
2. Neural Networks and Deep Learning By Michael Nielsen Online book, 2016
3. Deep Learning with Python By J. Brownlee
4. Deep Learning Step by Step with Python: A Very Gentle Introduction to Deep Neural Networks for Practical Data Science By N. D. Lewis
5. “Pattern Recognition and Machine Learning”, C.M. Bishop, 2nd Edition, Springer, 2011.
6. “Machine Learning for Audio, Image and Video Analysis”, F. Camastra, Vinciarelli, Springer, 2007. link http://www.dcs.gla.ac.uk/~vincia/textbook.pdf
7. "Automatic Speech Recognition: A Deep Learning Approach", D. Yu and L. Deng, Springer, 2016.
8. Aurelio Uncini, "Introduction to Adaptive Algorithms and Machine Learning", 2018 .
9. Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective". The MIT Press, 2012.97
10. Sergios Theodoridis, "Machine Learning: A Bayesian and Optimization Perspective". Elsevier, 2015.
11. Danilo Comminiello and José C. Príncipe (Eds.), "Adaptive Learning Methods for Nonlinear System Modeling". Elsevier, 2018

Master of Technology
in
Optical Engineering

Semester – VII

PH411 Optical Engineering Fundamentals (3 – 0 – 0) 3 credits

- Ray optics, Postulates of ray optics, Simple optical components, Matrix optics, The Ray-transfer matrix and Gaussian ray Optics, Wave and Electromagnetic optics, Elementary waves, Paraxial approximation, Effects of simple optical components on optical waves, Specular and diffuse reflection, refraction, transmission, absorption and scattering.
- Interference, diffraction and interferometers, Speckle and its application, Theory of optical coherence: Spatial and temporal coherence, van Cittert-Zernike theorem and its applications, Intensity interferometers, Phase problem of optics, Holography, Fourier transforms spectroscopy.
- Polarized light, Stokes parameters, Jones and Muller matrices, Partial polarization.
- Optical Imaging and Optical Instruments: The human eye, Microscopes and Telescopes, Confocal microscopes, Phase contrast microscope, Incoherent imaging techniques-X-ray tomography as an example, Optical coherence tomography, Polarimetric imaging, Synthetic aperture radar construction and application, LIDAR.
- Non-linear optics: Nonlinear optical media, second and third harmonic generation, parametric generation of light.
- Photon Optics: The Bohr atom, Energy Levels, Wave-particle duality, Light Quanta, Energy, momentum and velocity of photons, Development of quantum mechanics, Taylor's experiment.

References

1. Fundamental of Photonics, by Saleh and Teich
2. Fundamental of Optics: Jenkins and White
3. Principle of Optics, by Born and Wolf
4. Optics, by Hecht
5. Introduction to Optics, Pedrotti, Pedrotti, and Pedrotti
6. Polarized Light, by Goldstein
7. Laser Speckles and related phenomena, by Dainty
8. Nonlinear Optics, by Boyd
9. Modern Optical Engineering, by Smith

PH412 Opto-Mechanical Design Analysis (3 – 0 – 0) 3 credits

Introduction to Kinematic Mount Design (Basics).

Optical and Mechanical Materials: Material properties, Need for mechanical mounts. Stress Transfer Mechanism: Mechanical Design for minimum stress transfer. Design of Mechanical Mounts for Lenses and Mirrors: Gimbal Mount, Closed form solutions. Different categories of Mechanical Mounts, Fine Mechanics design, Linear and nonlinear movements; CAMS.

Fundamentals of theory of Elasticity, Finite Element principles, Analysis & optimization of simple lens and mirrors with mechanical mounts using FEM, Design of LTWT mirrors, FE modeling and analyses of LT WT mirrors, Zero-g and its relevance to space optics, Design approach for zero-g test beds, Modelling and design techniques against vibrational and thermal environment.

The course will be coupled with, Lab tutorial on FE modeling using FE modeling software as part of the main course.

Text Books/References

1. Principles of FEM by Logan
2. Fundamentals of Opto-mechanical Design –Paul Yodder
3. Award book of optical Design – Annes Ahmed
4. SPIE Vol. 1530 .Edited by –Annes Ahmed
5. Integrated Opto-mechanical Analysis by –Victor & Genbung
6. Optical Engineering – by Kingslake –Vol. IV, & Vol. XI
7. Opto-mechanical Systems Design, By Paul R. Yoder, Published by CRC Press, 2006

PH413 Optical Fabrication and Testing (3 – 0 – 0) 3 credits

Optical materials: Glasses, IR materials, Optical, mechanical and thermal properties of optical materials,Fabrication of lenses, mirrors and flats: spherical curve generation, polishing and figuring of "Curved Surfaces" of glass materials, Aspheric surface polishing/figuring, Polishing and figuring of IR materials:Ge, ZnSe and Zns, Advanced computer controlled polishing: Techniques, MRF polishing, Ion polishing,Micro-optics fabrication techniques, Large Mirrors fabrication techniques.

Testing of lens components : Measurement of parameters: focal length, refractive index, dispersion parameters. Surface error measurements by contact techniques, Testing of mirror components,Principles of interferometry contact/non-contact modes, Different interferometric techniques. Testing of lenses and Mirrors, interferometers: Twyman-Green, Fiezeau, Fabry-Perot and phase shifting interferometric techniques, Wavefront error analysis Zernike co-efficients evaluation.

Text Books/References

1. Fabrication methods for precision Optics" Hank H.Karow Wiley series, 2004
2. Hardware of optical Engineering" Daniel Malacaca –CRC press – B.J.Thompson 2001.
3. Optical Production Technology" Duglas f.Harve 1984(Edition -2) – Sky and Telescope
4. Telescope Optics", complete manual for smateur AstronomersHarie G.J. Sutten –M. H.M.V. Venorojaj -1988
5. Introduction to optical testing", Jolegn on – Geary 1993.
6. Optical Shop Testing" Daniel Malacna (Third Edition) 2007
7. Instrumentation analysis for Optical testing (Optical Engineering " D Malacna Z-Malacna CLC process -1998
8. Reflective Optics " D-Korpch 1991 –Academic process
9. Reflecting Telescope Optics –I" R.N.Wilson – 2002
10. Reflecting Telescope - Spinger – Vol. II
11. The design and construction of large optical Telescopes" Pierre Bely Springer – 2003 –Academic process

PH414 Lasers and Optoelectronics (3 – 0 – 0) 3 credits

Quantum Theory of Atomic Energy Levels – Radiative and Nonradiative decay of excited state atoms –Emission Broadening and linewidth – Radiation and Thermal equilibrium – Conditions for laser action –Laser Oscillation above threshold - Laser Amplifiers – Requirements for obtaining population inversion –Rate Equations for three and four level systems – Laser pumping requirements – Laser Cavity modes –Stable resonators – Gaussian beams– Special Laser Cavities – Q-switching and Mode locking –Generation of ultra fast Optical pulses– Pulse compression.

Atomic Gas Lasers – He-Ne, Argon ion, He-Cd — Molecular Gas Lasers – CO_2, Excimer, Nitrogen—X-Ray Plasma Laser — Free-Electron Laser — Organic Dye lasers — Solid-state lasers – Ruby, Nd:YAG, Alexandrite, Ti:Sapphire.

Electronic and Optical properties of semiconductors– electron-hole pair formation, PN Junction,diffusion, injection efficiency, quantum efficiency, homojunction and heterojunction, Excitation absorption, donor-acceptor and impurity band absorption, LED, Semiconductor lasers, Heterojunction Lasers, quantum well lasers, VCSEL, DFB and DBR Lasers.

Detection of Optical radiations – Basic Principle, Thermal detectors, Photo multipliers, photoconductive detectors, Photo diodes, Avalanche photodiodes, CCDs, Image Intensifiers, Arrays, Solar Cells, noise considerations.

Optoelectronic Modulators – Basic principle, Birefringence, Optical Activity, EO, AO and MO Effects and modulators**.**

Text Books/References

1. Laser Fundamentals – W.T. Silfvast, Second Edition, Cambridge University Press, 2004
2. Principles of Lasers – O. Svelto, Fourth edition, Springer, 1998
3. Photonics: Optical Electronics in Modern Communications – A. Yariv and P. Yeh, Sixth Edition,
4. Oxford University Press, 2007
5. Semiconductor Optoelectronic devices – Pallab Bhattacharya, Prentice Hall of India, 1995
6. Semiconductor Optoelectronics – Jasprit Singh, Tata McGraw Hill, 1995
7. Optoelectronics - an Introduction – Wilson and Hawkes, Prentice Hall, 1998

PH419 Fourier Optics (3 – 0 – 0) 3 credits

Introduction to linear vector spaces, bases and dimension, inner product, orthogonality, Fourier series,orthogonal polynomials, Cauchy Schwartz inequality, eigenvalues, eigenvectors, Hermitian operators,unitary operators, discrete Fourier transform.

Linear system theory and Fourier transformation. Properties of Fourier transform,Fourier transform theorems, some useful Fourier transform pairs, the delta function, circular symmetryand Fourier-Bessel transforms. General aspects of linear systems, Fourier transformation and spatial frequency spectrum, Linear space invariant and space variant systems. Sampling theory–Shannon-Whittaker sampling theorem.

Introduction to diffraction–general aspects. Fraunhofer and Fresnel diffraction. Scalar diffraction theory,Helmholtz equation and Greens theorem approach to Fresnel and Fraunhofer diffraction, the Huygens principle. Fourier transform in Fraunhofer diffraction. Examples of Fraunhofer diffraction such as Rectangular aperture, Circular aperture, Sinusoidal phase grating, sinusoidal amplitude grating, etc.

Fresnel transform, Fresnel diffraction such as square aperture, sinusoidal amplitude grating, etc. Fresnel propagation of a laser beam. Self imaging, Lau and Talbot effects, Fractional Fourier transform.

Wave optics analysis of coherent optical systems. Thin lens as a phase transformation,the paraxial approximation, Fourier transform properties of lenses. Image formation in monochromatic illumination.Diffraction–limited coherent imaging. Fresnel zone plate. Operator approach to optical systems.Frequency response of diffraction-limited coherent imaging – the amplitude transfer function (ATF).

Optical Transfer Function (OTF), frequency response of a diffraction-limited incoherent imaging. Aberrations and their effects on frequency response. Comparison of coherent and incoherent imaging. Resolution beyond the diffraction limit.

Text Books/References

1. Mathematical methods for physicists, Arfken and Weber, Academic Press, Sixth edition, 2005. (For unit 1)
2. Introduction to Fourier Optics, J. W. Goodman, McGraw-Hill. Third Edition, 2004 (For units 2, 3, 4, and 5)
3. Statistical Optics, J. W. Goodman, Wiley Inter-science, 2000. (Ref. for unit 5)
4. Fundamentals of photonics, Saleh and Teich, Wiley Interscience, 2007. (For unit 3)

PH431 Optics and Optoelectronics Lab (0 – 0 – 3)1 credit

- ☐ Diffraction - single slit ,double slit, aperture
- ☐ Spectrometer-dispersive power of grating
- ☐ Michelson interferometer
- ☐ Fabry-Perot interferometer
- ☐ Laser Beam profile
- ☐ Birefringence
- ☐ Fourier optics
- ☐ Stoke’s parameter
- ☐ Faraday effect
- ☐ Pockel effect
- ☐ Kerr effect
- ☐ Characterization of optical sources (LED, LD)
- ☐ Characterization of optical detectors (PD, APD)

PH432 Design and Analysis Lab (0 – 0 – 3) 1 credit

- Generation and deigning of different pupil functions/ and diffraction
- Evaluation of point spread function of
  - Diffraction limited system
  - Centrally obstructed system
  - Aberrated systems (Spherical aberration, coma and astigmatism)
- Evaluation of optical transfer function of the system of
  - Diffraction limited system
  - Aberrated systems
- Evaluation of phase transfer function of the imaging system
- Evaluation of the encircled energy of diffraction limited and aberated systems
- Aberrations compensations and its impact on the imaging system

PH452 Summer Internship and Training (0 – 0 – 0) 3 credits

Semester VIII

PH421 Guided Wave Optics and Optical Communication (3 – 0 – 0) 3 credits

Introduction to optical communication: Overview of General communication, advantage of optical communication, Basic characteristic of Optical Fiber Waveguides – Ray theory- Acceptance angle, Numerical aperture, Goos-Haenchen shift. Planar waveguides, Electromagnetic Modes in Planar waveguides and Cylindrical Waveguides, effective index method. Optical fibre and its propagation characteristics.Types of fibers, signal attenuation and losses in fibre, fiber manufacturing. Dispersion, classification and effect of dispersion in information transfer, dispersion management, dispersion shiftened, dispersion flattened, polarization maintaining fibers. Coupling between fibers, coupling losses.

Optical transmitter: Basic concepts, characteristics of semiconductor injection LASER, LED, VCSEL, DFB Laser, transmitter design

Optical Receiver: Basic concepts, p-n and pin photo detectors, Avalanche photo detectors, MSM photo detector, receiver design, receiver noise, receiver sensitivity, optical amplifier (EDFA, SOA) and its applications

Optical modulation: Direct and external modulation, electro-optic, electroabsorption, thermooptic effect and modulators. Various modulator configurations. Devices based on light coupling. (Directional coupler, ring resonator), fiber filters, FBG

Wavelength division multiplexing and demultiplexing (WDM and DWDM): devices for WDM and DWDM, OTDR. Unguided/Free-space optical communication systems. Optical integrated circuits, Shannon limit.

References:

1. Introduction to Fiber Optics, Ghatak and Thyagarajan, Cambridge University Press (2009)

2. Foundations for Guided wave Optics, Chin-Lin Chen, John Wiley and Sons

3. Optical Fiber Communications, Gerd Keiser, Fourth Edition, Tata McGraw Hill (2008)

4. Optical Fiber communications, J M Senior, Prentice Hall of India (1994

5. Communication system - B.P Lathi

6. Optical fiber communications: Principles and practice- John M. Senior-Prentice Hall of India

7. Optical communication systems-John Grower- Prentice Hall of India

8. Optical fiber communications- Gerd Keiser-McGraw Hill, 3 ed.

9. Non-linear optics – G.P Agarwal- Academic

10. WDM optical networks: concepts, design and algorithms- C.Sivaram murthy and Mohan Gurusamy- Prentice Hall of India, 2002

12.Understanding SONET/SDT and ATM communication network for next millenium- Stamatios V Kartalopoulos- Prentice Hall of India, 2000

12. Elements of Information theory, T M Cover and J A Thomas, Wiley, 2006

PH422 Adaptive Optics (3 – 0 – 0) 3 credits

Atmospheric turbulence – source of turbulence: free atmosphere, mirror seeing, dome seeing, boundary layer. Role of Kelvin-Helmoltz instability.Kolmogorov model of turbulance. Outer scale and inner scale,Reynolds number.

Optical effects of turbulence– derivation of: structure functions, covariance function, spatial coherence function, optical transfer function, effect of turbulence on spatial coherence function, effect of spatial coherence function on telescope resolution, derivation of fried parameter, isoplanatic angle, isokinetic angle, greewood frequency, angle of arrival fluctuations and tip-tilt.

Adaptive Optical systems : phase conjugation, conventional and unconventional adaptive optics, wavefront sampling, Wave front Sensing: Active and Adaptive Optics– Interferometeric techniques for wave front sensing, Hartmann, wavefront sensors. Indirect wave front sensing methods.

Wavefront correction: Test correction, multi-channel correction, segmented mirrors (MMDM) (SDM). Deformation mirrors, Bi-morphic corrections, membrane mirrors, Actuator deformable mirrors, Recent advances in deformable mirrors, Active optics: Large correcting optics, segmented mirrors.

Control systems – Principles of feedback control, implementation aspects to AO applications.

Implementation aspects – ground based system (Keck telescope) and space based system (James Webbtelescope), AO systems for future next generation astronomical telescope

Text Books/References

1. Principles of Adaptive Optics, Robert K Tyson, Second Edition, Academic Press
2. Selected papers of adaptive optics for atmospheric compensation by James E Pearson– SPIE proceedings-92 1994
3. Adaptive optics for Astronomical telescope by John W. Hardy (Oxford University press, 1998)
4. Introduction to Adaptive Optics by Robert K Tyson, technical tutorial 41 (SPIE press 2000)
5. Adaptive Optics in astronomy by Francois Roddier (Cambridge University Press 1999)
6. Field guide to Adaptive Optics by Robert K Tyson and Benjamin W Frazier, SPIE press.

PH423 Optical System Analysis and Design (3 – 0 – 0) 3 credits

Aberrations: Transverse ray and wave aberrations, chromatic aberration, Ray tracing: paraxial, finite and oblique rays, Image evaluation: transfer functions, point spread function, encircled energy and its computation and measurement, optimization techniques in lens design, merit function, damped least square methods, orthonormalization, and global search method, Tolerance analysis; Achromatic doublets, achromats and aplanats; Cooke triplet and its derivatives; Double Gauss lens, Zoom lenses and aspherics, GRIN optics, focal shift, high and low N number focusing systems, focusing of light in stratified media, high numerical aperture focusing, basics of non-paraxial propagation of light.

Classification of lens systems. Refractive systems – Cookes triplet, Gatelecentric system, telephoto system, f-theta lens (fish eye lens); Relective systems – single mirror telescope, two mirror telescope –Greogrian, Dall-Kirkham, Marsenne, Cassegrain, R-C telescope, three mirror aspheric system : unobscured system, obscured system.

Text Books/References

1. Principles of Computerized Tomographic Imaging. -A. C. Kak and Malcolm Slaney. IEEE Press
2. Biomedical Optics: Principles and Imaging. - Lihong V. Wang and Hsin-i Wu. Wiley-Interscience.
3. A. P. Gibson, J. C. Hebden, and S. R. Arridge, "Recent advances in diffuse optical imaging", Physics in Medicine and Biology, 50, R1-R43. (2005).
4. S.R.Arridge "Optical tomography in medical imaging", Inverse Problems, 15, R41–R93. (1999)
5. "Introduction to Fourier Optics" J. W. Goodman
6. "Polarization holography" L. Nikolova & P.S. Ramanujam
7. "Optical holography principles techniques and applications" P. Hariharan

PH4xx PG Elective I (3 – 0 – 0) 3 credits

PH4xx PG Elective II (3 – 0 – 0) 3 credits

PH441 Guided Wave Optics Lab (0 – 0 – 3) 1 credit

- ☐ Measurement of numerical aperture
- ☐ Measurement of bending losses
- ☐ Measurement of fiber losses
- ☐ Optical fiber communication Trainer
- ☐ Setting up - fiber optic digital link
- ☐ Setting up - fiber optic analog link
- ☐ TDM of signals
- ☐ OTDR
- ☐ Fiber Laser
- ☐ Fiber Optics Workshop

PH442 Adaptive Optics Lab(0 – 0 – 3) 1 credit

- ☐ Numerical modeling on point spread function of perfect and aberrated systems
- ☐ Numerical modeling on focusing by lens let arrays
- ☐ Numerical modeling on the image formation by perfect/and aberracted systems
- ☐ Numerical modeling of Zernike polynomials of the aberrated wavefront
- ☐ Experiment with wavefront sensor:
  - ◦ Measurement of aberrated and un-aberrated wavefront
  - ◦ Corrections of aberrated wavefronts
  - ◦ Evaluation of Zernike polynomials

PH451 Seminar (0 – 0 – 0) 1 credit

Semester IX

PH551 Project Phase I (0 – 0 – 0) 13 credits

PH552 Comprehensive Viva-Voce II (0 – 0 – 0) 2 credits

Semester X

PH554 Project Phase II (0 – 0 – 0) 20 credits

PG Elective Courses

PH461 Optical Thin Films Science and Technology (3 – 0 – 0) 3 credits

Propagation of electro-magnetic in stratified dielectric medium, Fresnel equations Optical properties of materials, metals, semiconductors and dielectrics, optical glass materials in the visible and near infrared region, IR optical materials, Multilayer thin film optics, Antireflection coatings, Band pass optical filters, edge filters, dichroics, Design –Optimization techniques for thin film multilayer, Merit function as applied to thin film coatings. Brief review of different optimization techniques as applied to optical coatings. Case studies for design approaches for different categories of optical coatings. Exposure to thin film software packages. Concept of linearly variably and circularly variable filters, Tunable optical filters. Reflective coatings, enhanced reflectors.

Thin film technology: Vacuum Science: Viscous, Lamellar and molecular fluid region, Medium, High and Ultra-high vacuum techniques. Mechanical and High vacuum pumps, ultra-high vacuum pumps. High vacuum measurement techniques, principle, calibration and electronics read out Deposition and production of optical thin films: Thin film deposition techniques thermal/electron beam evaporation, RF/DC sputtering, Ion beam sputtering, pulsed laser beam deposition. In-situ thickness monitoring: Optical and quartz micro-balance techniques monitoring techniques. Architecture of modern day coating plants.

Characterization of optical thin films: Principles of characterization of optical reflectance, transmittance, absorbance and angle resolved scattering. Principles of spectrophotometers and ellipsometers. FTIR spectrometers Characterization of non-optical properties of thin films: Mechanical adhesion, abrasion and hardness. Surface characterization techniques for thin films: Surface morphology, X-ray structure, Chemical composition. SEM, TEM and AFM instruments for thin film characterization.

Space qualification: Different environments encountered by Optical components in ground during storage, instrument assembly and testing, launching and in deep space. Adverse environmental conditions in deep space. Radiation environment in space. Space Qualification of Optical coatings and materials. Effect of space environment on optical materials and thin films.

Text Books/References

1. Thin film optical filters, Angus Macleod
2. Principles of optics, Born and Wolf
3. SPIE milestone series on -Design of optical coatings
4. Optical Thin films – User hand book – James D Rancourt SPIE Press – 1996 – ISBN 0819422851
5. Practical Design and Production of Optical Thin Films – Second Edition – Ronald Ron Wiley –CRC Press – 2002 ISBN 0824708490
6. Handbook of Thin Film Technology- Leon –Imaissel & Reihard Glang –Mc Graw –Hill Book Company -1970 –ISBN 0070397422
7. Essential Macloed Software, By Angus Macleod

PH462 Optical and Electro-Optical Sensors (3 – 0 – 0) 3 credits

Sensor Overview: Photometry and Radiometry, Radiation Sources and characteristics. Detectors-Imaging and non imaging [Thermal detectors , Photon detectors, Detector arrays : CCDs, CID, FLIR etc.] and their characteristics.

Sensor optics, Sensor instrumentation, Signal processing techniques Space craft sensors: Optical Attitude Sensors: Fiber Optic gyros [with integrated optics], Ring Laser Gyros,Star sensors – Spacecraft attitude determination and control. Line of Sight Sensors – IR Earth sensor, Sun Sensors, Star Sensor &Trackers. Sensors/System for Space craft precision Pointing and navigation. Imaging sensors: Remote sensing sensors for Earth observation, Cartography Hyper spectral Sensors.

Modeling, design, analysis, calibration and Performance evaluation of the above. System Integration and Testing. Optical, Integrated and Fiber optic sensors: Acceleration, Displacement and Velocity sensors [anemometer], Position – linear and Angle encoders, temperature , strain etc Fiber optics based smart sensors for Space applications : MOEM Sensors, Large optical Systems for space born camera applications.: Design, Fabrication and Testing.

Text Books/References

1. Fundamentals of Space Systems by Vincent L. Pisacane, Oxford University Press, 2005
2. Spacecraft dynamics and Control: A practical Engineering approach- Marcel J.Sidi, Contributor Michael J.Rycroft, Wei Shyy, Cambridge University Press, 2000
3. Spacecraft Attitude determination and Control by Computer Sciences, Corporation Attitude Systems operation, James Richrad Wertz, Springer, 1978
4. Scientific Charge Coupled devices, James R.Janesick, SPIE Press
5. Laser Gyros and Fiber optic Gyros: Proceedings London Royal Aeronautical Society 1987
6. Fiber optic sensor-based smart materials and structures- By Claus, Richard O,Knowles, G J Bristol, Institute of Physics Publishing, 1992
7. Fiber optic gyroscope- By Lefevre, Herve,Boston ,Arcteh House, 1993
8. Laser Inertial Rotation Sensors-proceedings- By Ezekiel, Shaoul, Knausenberger, G E Washington, Proceedings of SPIE. v157, 1978
9. Handbook of fiber optics : Theory and applications, Yeh, Chai, Academic Press, Inc., 1990

PH463 Integrated Optics (3 – 0 – 0) 3 credits

Compensating TE modes of a symmetric step index planar, understanding modes, TE modes of parabolic index planar waveguide, TM modes of a symmetric step index planar waveguide, waveguide theory, Single mode fibers, pulse dispersion in single mode fibers, strip and channel wave guides, anisotropic waveguides, segmented waveguide, electro-optic and acousto optic waveguide devices, directional couplers, optical switch phase and amplitude modulators, filters etc, Y junction, power splitters, arrayed waveguide devices, fiber pigtailing, fabrication and integrated optical waveguides and devices, waveguide characterization, end-fire prism coupling, grating and tapered couplers, nonlinear effects in integrated optical waveguides.

Text Books/References

1. Integrated Optics-Theory and Technology, R G Hunsperger, Sixth edition, Springer (2009)
2. Optical Waveguide Theory, A W Snyder and J D Love, Chapman & Hall, London (1983)

PH464 Introduction to Quantum Optical Technologies (3 – 0 – 0) 3 credits

Quantum Mechanics: Fundamentals

Quantum Mechanics basic ideas, Wave particle duality, Davisson-Germer experiment (Other experiments regarding wave particle duality), Stern Gerlach experiment, Kets, Bras and Operators, Projective measurement, Observables, Quantum probabilities and Expectation values, Spin-1/2 systems and qubit. (*9 lectures*)
Wave packets and the uncertainty relations, The schrodinger wave equation, Particle in a box: energy eigenvalues and eigen states, Harmonic oscillator: ladder operators, energy eigenvalues and energy eigen states. (6 *lectures*)

Quantum Optics: Fundamentals

Quantization of the electromagnetic field, Quantum states of radiation: coherent and squeezed states and properties, $\chi^{(2)}$ and $\chi^{(3)}$ non-linear interactions, Twin-photon generation with non-linear interactions, Spontaneous parametric down-conversion, Optical parametric amplifiers. (*8 lectures*)

Linear Optics with Quantized Fields:

Beam splitter transformations, Theory of photodetection, Direct, balanced, and homodyne detection. (*4 lectures*)

Photon Statistics, Single Photon Sources and Detectors:

Introduction to quantum coherence, Hanbury-Brown Twiss experiment, Photon-bunching and anti-bunching, Single-photon sources and single photon detectors. (4 *lectures*)

Quantum Optical Technologies

Quantum superposition, Photonic qubit and photonic entangled states, Measuring the polarization of a single photon, Photon pairs and joint polarization measurements, Bell's theorem and Bell's inequality: CHSH Variant (*4 lectures*)

Introduction to key photonic technologies:

The quantum advantage in interferometry, Quantum imaging, Quantum key distribution, Quantum dense coding and quantum teleportation, Linear optical quantum computing, and Quantum metrology. (10 *lectures*)

References

1. Modern Quantum Mechanics, by Sakurai
2. Introductory Quantum Optics, by Gerry and Knight
3. A Guide to Experiments in Quantum Optics, by Hans and Bachor
4. Quantum Computation and Quantum Information, by Nielson and Chuang
5. Introduction to Quantum Optics: From the Semi-classical Approach to Quantized Light, by Aspect, Fabre, and Grynberg.

PH465 Advanced Optoelectronics (3 – 0 – 0) 3 credits

Review of Semiconductor device Physics, Semiconductor Opto electronics- Solid State Materials, Emitters, Detectors and Amplifiers, Semiconductor Emitters- LEDs, Diodes, SLDs, CCDs, Semiconductor lasers- basic Structure, theory and device characteristics, DFB, DBR, Quantum well lasers ,Laser diode arrays, VCSEL etc. Semiconductor photo detectors:Materials - Si, Hg Cd Te, InGa As, Al Ga As, GaN etc for different wavelengths.

Detectors: Photoconductors, photo diodes, PIN , APD ,Photo transistors, solar cells, CCDs, IR and UV detectors.

Band gap Engineering, Quantum well structures, size effects, Hetero and nano structures. Fabrication techniques [MBE, CVD, Lithography, Thin films technoloy] and Device characterization. Integrated Optics- Optical wave guide theory, wave guide structures. Fiber optic interconnects- Fiber lasers and amplifiers, fiber sensors.

Optoelectronic Integrated Circuits [OEIC]- Directional couplers, Dividers, Multiplexers, Phase and Amplitude Modulators, Polarization and polarization controllers, etc. Photonics Signal processing, Nonlinear optics- Frequency Converters, Phase conjugation, optical Correlation etc.

Photonic devices and applications for aerospace: Intensity, phase and polarization based Fiber optic sensors for measurement of temperature, pressure, stress etc for space craft health monitoring, Hydrogen leakage sensing in cryo engines. Fiber Optic Gyroscope for navigation application. Optical Intra Satellite links using ELED's, VCSELs. Fiber Bragg gratings for health monitoring and smart materials: applications in aerospace.

Text Books/References

1. Physics of Opto-electronic Devices- Shun Lien Chuang-Wiley, John&Sons-2009
2. Physics of Semiconductor devices-S.M.Sze & Kwok K Ng, Third edition,Wiley-2007[parts I, II and IV]
3. Infrared Photon detectors-Antoni Rogalski [Ed]-SPIE Optical Engineering Press-1995
4. CCD arrays, Cameras & Displays-Gerald C Hoist 1998 [2nd Ed], JCD Publishing-SPIE Optical Engg.Press

5. Fundamentals of Photonics, by Bahaa E. A. Saleh and Malvin Carl Teich, Wiley Series in Pure and Applied Optics
6. Photonic Devices By Jia-Ming Liu Cambridge University Press, 2005
7. Photonic Devices and Systems –by Robert G. Hunsperger, Taylor & Francis, 1994

PH466 Statistical and Quantum Optics (3 – 0 – 0) 3 credits

Introduction to probability theory, properties of probabilities, random variabes and probability distribution, generating functions, examples of probability distributions, Gaussian probability distribution, central limit theorem, multivariate Gaussian distribution. Random processes, statistical ensembles, stationarity and ergodicity, properties of autocorrelation function, spectral properties of stationary random processes, orthogonal representation of a random process, Wiener Khinchine theorem, Karhunen–Loeve expansion.

Second order coherence theory of scalar wave fields, temporal coherence, spatial coherence, the laws of interference, the mutual coherence function and the complex degree of coherence, cross spectral density, partial coherence and spectral degree of coherence, Wigner function, propagation of cross–spectral density and mutual coherence in free space, the van Cittert–Zernike theorem and its application in stellar interferometry.

Elementary theory of polarization of stochastic electromagnetic beams. Polarized, unpolarized, and partially polarized light. Partially polarized light and the degree of polarization. Stokes parameters and the Poincare sphere. Unified theory of polarization and coherence. Spectral degree of coherence and stochastic electromagnetic beams, generalized stokes parameters.

Position and momentum kets, displacement operator. Wave functions in position and momentum space, the uncertainty principle. Simple harmonic oscillator, annihilation and creation operators, Fock basis, time evolution. Coherent, squeezed, and thermal states of a single–mode. Quantization of the electromagnetic field.

Represention of a state, Fock basis expansion, coherent state expansion, diagonal representation, Wigner phase space density, and the Q function, s-ordered quasi-probability. Normal, symmetric, and anti–normal ordering of operators. Classical and non-classical states of radiation with examples.

Field correlation functions, properties of correlation functions, correlation functions and optical coherence. Photon correlation measurements, photon counting measurements, Intensity – intensity correlation $g2\ (\tau)$. The quantum mechanical beam-splitter, the quantum mechanical amplifier. Two-mode squeezed vacuum.

Text Books/References

1. Statistical Optics, J. W. Goodman, Wiley–Interscience, 2000. (units 1, 2, and 3).
2. Optical Coherence and Quantum Optics, L. Mandel and E. Wolf, Cambridge University Press, 1995. (units 1, 2, and 3).
3. Introduction to theory of coherence and polarization of light, E. Wolf, Cambridge University Press, 2007. (units 2 and 3).
4. Modern Quantum Mechanics, J. J. Sakurai, Pearson Education, 2009. (unit 4).
5. Optical Coherence and Quantum Optics, L. Mandel and E. wolf, Cambridge University Press, 1995. (units 4, 5, and 6).
6. Quantum Optics, D. F. Walls and G. J. Milburn, Springer, 2007. (units 4, 5, and 6).
7. The quantum theory of light, R. Loudon, Oxford university press, 2000. (units 4, 5, and 6).

PH467 Non-Linear Optics (3 – 0 – 0) 3 credits

Nonlinear optical susceptibility, wave equation description of nonlinear optical interactions - Sum frequency generation, Difference frequency generation, Second Harmonic generation, Phase matching condition, Optical parametric Oscillators, Quantum mechanical theory of nonlinear optical susceptibility- Schrodinger equation calculation, density matrix calculation. Spontaneous light scattering and acoustooptics, Stimulated Brillouin Scattering, Stimulated Rayleigh Scattering, Stimulated Raman Scattering, Second harmonic generation, parametric processes, 3rd order nonlinear optics, Kerr type nonlinearities, 4-wave mixing, self focusing collapse, optical breakdown, two beam coupling, electrooptics and photorefractive effects, optically induced damage and multiphoton absorption, Ultrafast and intense field nonlinear optics and optical solitons.

Text Books/References

1. Nonlinear optics, second Edition, Robert W Boyd, Academic Press (2003)
2. Photonics-Optical Electronics in Modern communications, A Yariv and P Yeh, Sixth edition, Oxford University Press (2007)
3. The Principles of nonlinear Optics, Y R Shen, Wiley-Interscience, 1991
4. Handbook of Nonlinear Optics, R L Sutherland, Marcel Dekker, 1996

PH468 MEMS and MOEMS (3 – 0 – 0) 3 credits

I. **Introduction to MEMS and MOEMS**
Introduction to MEMS Technology and Applications
Introduction to sensing and actuation principles, applications, various types of sensors and actuators
Open loop and closed loop systems
Materials used for MEMS fabrication and reasons to select them
Design of Microstructures with specific case studies like accelerometers, gyroscopes, RF switches
Silicon micromachining and its opportunities

II. MEMS Devices: Fabrication and Technologies
Types of micromachining and device architecture: Bulk, surface, LIGA, Silicon on Glass
Types of wafers and wafer selection approach for microfabrication
Various processes for microfabrication
Process technologies and machines for fabrication like Lithography, Wet and dry etching, Deep Reactive Ion etching, wafer bonding techniques, thin film deposition technologies, oxidation
Characterization and process recipe development approaches

III. Characterization, Packaging, Calibration and Reliability assurance of MEMS products
Performance testing of microdevices
Technologies used for inspecting and characterizing devices – vibrometers, surface profilers, SEM
Integration of readout electronics to MEMS
Technologies for packaging of MEMS devices
The importance of calibrating an instrument
Approach for calibration of devices like pressure sensor and accelerometers
Reliability assurance approaches, Failure modes, Failure mode and effects analysis, Quality assurance tests

IV. MEMS and MOEMS devices for Aerospace, Biomedical and Industrial applications
Specific case studies for development and use of MEMS devices in space applications – sensors, actuators, science payloads
MEMS based products in thermal engineering, microfluidics, biomedical applications
Products based on MOEMS technology, micro-optic components and their applications
Role of MEMS in IoT, Industrial Applications

Text Books and References:

1. Nodium Maluf, “Introduction to Micromechanical Systems Engineering”,
2. Marc Madou “Fundamentals for Microfabrication”,
3. Elwenspoek “Silicon Micromachining” ,
4. Barkley Sparks: “Microelectromechanial Systems: Concepts, Design and Analysis”
5. MOEMS, SPIE Press USA

PH469 Laser Applications (3 – 0 – 0) 3 credits

Laser for detection and ranging- LIDAR applications-Doppler wind LIDAR, Differential Absorption LIDAR for water vapor monitoring. Laser application in material processing – esp. CO2, YAG , Excimer,Ruby lasers- [material processing, Cutting, Welding, drilling, micro machining] – Interation of laser radiation with matter, Heat Flow Theory, Process characteristics etc. Laser anemometry, Schlieren Techniques for wind tunnels, Holography etc Lasers for metrology – Interferometery for surface characterization, precision length measurement, time standards etc, Medical applications of laser.

Lasers for space applications – free space communication, laser propulsion, laser ignition,Optical Rotation sensors and their applications for space navigation: Sagnac Interferometers and their applications for space, Fiber Optic Gyros –Fibers, Guided Wave optics, Sources and detectors for Fiber Optic Sensors, Fiber optic couplers, modulators etc, Closed and open loop Fiber optic gyros – configurations, design and application for space navigation, Fiber optic acceleration sensors. Ring Laser gyros- Laser Resonator Design, Laser Frequency stabilization techniques, Ring resonator – stable and unstable and their application in Ring Laser

Gyros, Fabrication and metrology of precision laser optics. Ultra High vacuum [production, measurement] techniques relevant to Gas laser processing. Optical gyros error modeling, error compensation, test methodologies and applications for inertial navigation.

Application of Digital Holographic Interferometry in optical metrology, Laser Doppler velocimetry, Laser-induced breakdown spectroscopy (LIBS), Laser-induced fluorescence (LIF), Laser tweezers and applications, Laser Heterodyne Spectroscopy.

Text Books/References

1. Quantum Elecrtronics, Amnon Yariv, John Wiley [1989]
2. Lasers, Siegman, Anthony E California/University of Science Books/1986
3. Physics of gas lasers, Bennett, W R/Montroll, Elliot W, New York/Gordon and Breach/1977
4. Introduction to gas lasers : Population inversion mechanisms, Willett, Colin S/Haar, D Ter, Oxford/Pergamon press/1974
5. Laser resonators and beam propagation, Hodgson, Norman/Weber, Horst New York/Springer Science/2005, Springer series in optical sciences
6. Physics and technology of laser resonators. HALL, Denis R/JACKSON, Paul E Bristol/Adam Hilger/1989,
7. Laser gyros and fibre optic gyros : Proceedings, London/Royal aeronautical society/1987.
8. Ring laser gyro (RLG) technology, Filatov, Yuri Chennai/1999
9. Laser applications,V.1, ROSS, monte, New York/Academic Press
10. Engineering applications of lasers and holography, Kock, Winston E/WOLFE William L New York/Plenum press/1975
11. Fiber-optic gyroscope, Lefevre, Herve, Boston/Arcteh House/1993

PH470 Quantum Optical Communication (3 – 0 – 0) 3 credits

Quantum theory of light: quantization of the electromagnetic field, evolution of the field operators, quantum states of the electromagnetic field. Quantum information processing: quantum information, quantum communication, quantum computation with qubits, quantum computation with continuous variables. Density operators and super operators, fidelity, entropy, information and entanglement measures, correlation functions and interference of light, photon correlation measurements. Photon sources and detectors: Mathematical model of photodetectors, physical implementations of photodetectors, single-photon sources, entangled photon sources, quantum non-demolition photon detectors. Quantum communication with single photons: photons as information carriers, quantum teleportation and entanglement swapping, decoherence-free subspaces for communication, quantum cryptography. Quantum computation with single photons. Quantum communication with continuous variables: phase space in quantum optics, continuous-variable entanglement, teleportation and entanglement swapping, entanglement distillation, quantum cryptography. Quantum computation with continuous variables. An ensemble of identical two-level atoms, electromagnetically induced transparency, quantum memories and quantum repeaters, the atomic ensemble of a single qubit, photon-photon interactions via atomic ensembles, Solid-state quantum information carriers: Definition and optical manipulation of solid-state qubits, interactions in solid-state qubit systems, entangling two-qubit operations, scalability of solid-state devices.

Text Books/References

1. P. Kok and B. W. Lovett, Introduction to Optical Quantum Information Processing, Cambridge university press.
2. L. Mandel, and E. Wolf. Optical Coherence and Quantum Optics, Cambridge University Press.
3. W. H. Louisell, Quantum Statistical Properties of Radiation, McGraw-Hill.
4. D. Bouwmeester, A. K. Ekert, and A. Zeilinger, eds. The Physics of Quantum Information, Springer

PH471 Nano Optics (3 – 0 – 0) 3 credits

Theoretical Foundations: Macroscopic electrodynamics, wave equations, time harmonic fields, Dyadic Green's function, Evanescent fields. Propagation and focusing of optical fields – field operators, paraxial approximation of optical fields, polarized electric and magnetic fields, focusing of fields, point spread function, principles of confocal microscopy, near field optical microscopy, scanning near –field optical microscopy.

Nanoscale optical microscopy – far field illumination and detection, near field illumination and far-field detection, far field illumination and near field detection, energy transfer microscopy. Near –field optical probes- dielectric probes- conical, tapered, tetrahedral, Aperture probes. Probe –sample distance control.

Light emission and optical interactions in nanoscale environments- mutipole expansion, radiating electric dipole, spontaneous decay, delocalized excitations, Quantum emitters, dipole emission near planar interfaces, Light in periodic structures: Photonic crystals and resonators, Surface plasmons. Meta materials.

Text Books/References

1. Principles of Nano-optics, L Novotny and B Hecht, Cambridge University Press (2006)
2. Introduction to Nanophotonics, S V Gaponenko, Cambridge University Press (2010)
3. Nanophotonics, H Rigneault(Ed.), ISTE (2006)
4. Principles of nanophotonics, Motoichi Ohtsu, CRC Press, (2008)

Master of Science
in
Solid State Physics

Semester – VII

PH415 Advanced Solid State Phvsics (3 – 1 – 0) 4 credits

Second quantization: Fock-space representation for bosons and fermions, representation of many-body operators.

Electron-electron interaction: Hartree and Hartree-Fock approximations; Quasiparticles, Landau-Fermi liquid theory for interaction between quasiparticles, equilibrium properties of normal Fermi liquid, ^{3}He: ideal Fermi liquid, transport of quasiparticles, current density.

Magnetism: Absence of magnetism in classical statistics; Origin of the exchange interaction; direct exchange, super exchange, indirect exchange and itinerant exchange; spin Hamiltonians: Heisenberg model; ground state of Heisenberg ferromagnet and antiferromagnet; spin wave analysis, mean-field theory, spontaneous magnetization, ordered manetism of valence and conduction electrons, Stoner's criterion for metallic ferromagnet.

Superconductivity: Meissner effect, Type I and Type II superconductivity, Ginzburg-Landau theory, gauge symmetry and symmetry breaking, flux quantization; Electron-electron interaction via lattice: Cooper pairs, BCS theory. Josephson tunneling, ac and dc Josephson effect; Vortex state (qualitative discussion); High T_c superconductors (qualitative discussion).

Special topics: Mott transition, Hubbard model, Kondo effect, Superfluidity.

Text Books/References

1. Michael P. Marder, Condensed Matter Physics, John Wiley & Sons.
2. Neil W. Ashcroft and N. David Mermin, Solid State Physics, Harcout College Publishers.
3. Charles Kittel, Introduction to Solid State Physics, John Wiley & Sons.
4. David Pines and Philippe Noziers, The Theory of Quantum Liquids, W. A. Benjamin Inc.
5. A. C. Rose-Innes and E. H. Rhoderick, Introduction to Superconductivity, Pergamon.
6. H. Ibach and H. Luth, Solid State Physics: An Introduction to Theory and Experiment, Springer.

PH416 Ouantum Mechanics II (3 – 1 – 0) 4 credits

Approximation methods: Variational methods, WKB approximation; time-indepdndent perturbation theory; time-dependent perturbation theory: Interaction picture, Fermi's golden rule, sudden and adiabatic approximations.

Scattering theory: Transition rates and cross sections, Lippmann-Schwinger equation, scattering amplitude, Green's functions; Born approximation; phase shifts and partial waves.

Symmetries in quantum mechanics: Continuous symmetries: space and time translations, rotations; rotation group and its irreducible representations; Irreducible spherical tensor operators, Wigner-Eckart theorem. Discrete symetries: parity and time reversal.

Identical particles: Meaning of identity and consequences; symmetric and antisymmetric wavefunctions; Slater determinant.

Relativistic Quantum Mechancis Klein-Gordon equation; Dirac equation, free particle solution, electromagnetic interaction of the Dirac particle, spin and magnetic moment of the electron.

Special topics: Path integral formalism; basics of quantum information: entanglement, Einstein-Podolsky-Rosen paradox, Bell's inequality, coherent states.

Text Books/References

1. J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley.
2. R. Shankar, Principles of Quantum Mechanics, Springer.

3. C. Cohen-Tannoudji, et al., Quantum Mechanics, Wiley-Interscience.
4. A Peres, Quantum Theory: Concepts and Methods, Kluwer Academic Publishers.

PH417 Semiconductor Physics (3 – 0 – 0) 3 credits

Semiconductor in equilibrium: Equilibrium distribution of electrons and holes, qualitative description of dopant atoms and energy levels, equilibrium distribution of electrons and holes in extrinsic semiconductor, degenerate and non-degenerate semiconductors, statistics of donors and acceptors, probability function, compensated semiconductors, Fermi energy levels and its variation with doping concentration and temperature, relevance of Fermi energy.

Carrier transport phenomena: Carrier drift current density, mobile effects, conductivity, velocity saturation, carrier diffusion current density, total current density, graded impurity distribution and the Einstein's relation.

Non-equilibrium excess carriers in semiconductors: Carrier generation and recombination, characteristics of excess carriers, continuity equations, time-dependent diffusion equations, derivation of ambipolar transport equation, dielectric relaxation and its time constant, quasi-Fermi energy levels, surface effects.

The p-n junction: Basic structure of the p-n junction, zero applied bias, reverse applied bias, non-uniformly doped junctions, qualitative description of charge flow in a p-n junction, small-signal model of the p-n junction, generation-recombination currents, junction breakdown, charge storage and diode transients, tunnel diode.

Metal-semiconductor and semiconductor heterojunctions: The Schottky barrier diode, metal-semiconductor ohmic contacts, tunneling barrier, heterojunctions, heterojunction materials, equilibrium electrostatics, current-voltate characteristics.

Bipolar transistor: Basic principle of operation, minority carrier distribution, low-frequency common-base current gain, non-ideal effects, switching characteristics, the Schottky-clamped transistor, polysilicon emitter BJT, heterojunction bipolar transistors.

Special topics: Fundamentals of metal-oxide semiconductor field-effect transistor, energy band diagrams, non-ideal effects in MOSFETs, radiation and hot-electron effects, junction FETs, optical devices.

Text Books/References

1. Donald A. Neamen, Semiconductor Physics and Devices: Basic Principles, McGraw-Hill.
2. S. Wang, Fundamentals of Semiconductor Theory and Device Physics, Prentice Hall.
3. M. Shur, Physics of Semiconductor Devices, Prentice Hall.

PH418 Experimental Physics (2 – 0 – 3) 3 credits

Essential techniques: Probability distributions and statiscs, error analysis and error propagation, covariance, least-square fitting. Vacuum technology: gas flow equations, flow regimes, types of pumps, gauges and seals. Sensors and analog instrumentation: analog signal processing. Lock in amplifiers and applications: measurements in noise prone environments. Digital electronics: microprocessors and micro-controllers, ADC/DAC, PLCs, computer interfaces. Virtual instrumetation: General purpose instrumentation and interface, virtual instrumentation techniques and programming.

Fundamental methods in experimental physics: Coincidence techniques in time correlated measurements. Null measurements. Spectroscopy: Spectrophotometers, Laser Raman spectroscopy, Resonance spectroscopy, NMR, ESR, Mossbauer spectroscopy. Mass spectrometry and applications. Cryogenics: production, measurement, low and ultra-low temperatures using liquid nitrogen. He cryostats, adiabatic and nuclear de-magnetization, dilution refrigerators.

Text Books/References

1. John H. Moore, Christopher C. Davis, Michael A. Coplan, Building Scientific Apparatus, Westview press Inc. 3rd revised ed. 2002

2. G. L. Weissler, Robert Warner Carlson, Methods of Experimental Physics Vol. 14: Vacuum Physics and Technology, 1st ed., Academic press, 1980.
3. R. V. Coleman, Methods of Experimental Physics Vol. 11: Solid State Physics, Academic press, 1974.
4. Methods of Experimental Physics Vol 22: Surfaces, Academic press, 1985.

E03 Institute Elective (3 – 0 – 0) 3 credits

PH433 Solid State Physics Lab II (0 – 0 – 3) 1 credit

PH452 Summer Internship and Training (0 – 0 – 0) 3 credits

Semester – VIII

PH424 Advanced Statistical Mechanics (3 – 1 – 0) 4 credits

Phase Transitions and Critical Phenomena

General Introduction: Origin of phase transition, thermodynamic instabilites, Maxwell construction. Classification of phase transitions: first order and second order. Phase transitions in different systems (e.g. liquid-gas and paramagnet-ferromagnetic transition), order parameter, critical exponents, concept of long-range order.

Lattice models: Ising Model, exact solution in one dimension, high-temperature and low-temperature expansions. Phase transitions in X-Y and Heisenberg Models.

Mean field theory and Landau theory. Landau-Ginzburg theory for fluctutations.

Sponteneous symmetry breaking, Introduction to Mermin-Wagner theorem.

Quasi-long-range order, Kosterlitz-Thouless transition. Renormalization Group: scaling hypothesis and universality, renormalization group transformation. Upper and lower critical dimensions, epsilon-expansion.

Introduction to nonequilibrium Statistical Mechanics. Markov Processes, Master equation, Langevin Equation.

Text Books/References

1. M. Plischke and B. Bergersen, Equilibrium Statistical Physics.
2. J. Cardy, Scaling and Renormalization in Statistical Physics.
3. R. Kubo, M. Toda, N. Hashitsume, Statistical Physics II: Nonequilibrium Statistical Mechanics.
4. S-K Ma, Statistical Mechanics, World Scientific.

PH425 Computational Physics (2 – 0 – 3) 3 credits

Errors and uncertainties in computations: Types of errors, error in functions, errors in algorithms. Matrix computing and scientific libraries.

Zero-finding and matching: Newton's rule for finding roots. Quantum eigenvalues, particle in a box. Fields due to moving charges.

Integration: Trapezoid rule, Simpson's rule, Gaussian quadrature, multi-dimensional integrals. Monte-Carlo integrations.

Differential equations: Euler's algorithm, Runge-Kutta methods. A forced non-linear oscillator, motion of a charegd particle in an electric field, dynamics of non-linear systems. Numerical solutions of boundary value probems: solution of Laplace equation and Poisson's equation. Heat flow in a meta bar, waves on a string. Born and Eikonal approximations to quantum scattering, partial wave decomposition of the wave function. Solitons. Confined electronic wave packets: time-dependent Schrodinger equation.

Data fitting: Lagrange interpolation, cubic splines, least-square fitting. Fitting exponential decay, fitting heat flow. Non-linear least-squares fitting.

Fourier analysis. Fourier spectral methods. Harmonics in non-linear oscillations. Discrete Fourier transform. Highly non-linear oscillator, Processing noisy signals.

Random walk simulations. Decay simulation, Monte-Carlo simulations. The Ising model, Metropolis algorithm. Molecular dynamics simulations.

Text Books/References

1. S. E. Koonin, Computational Physics, Westview, 1990.
2. R. H. Landau, M. J. Paez, Computational Physics: Problem Solving with Computers, Wiley-VCH, 2004.
3. H. Gould, J. Tobochnik, W. Christian, An Introduction to Computer Simulation Methods: Applications to Physical Systems, Pearson, Addison-Wesley, 2007.
4. P. L. Devries, J. E. Hasbun, A First Course in Computational Physics, Jones & Bartlett, 2011.
5. J. P. Boyd, Chebyshev and Fourier Spectral Methods, Dover, 2001.

PH4xx PG Elective I (3 – 0 – 0) 3 credits

PH4xx PG Elective II (3 – 0 – 0) 3 credits

PH453 Mini Project (0 – 0 – 0) 2 credits

PH443 Solid-State Physics Lab III (0 – 0 – 3) 1 credit

PH454 Comprehensive Viva-Voce II (0 – 0 – 0) 2 credits

Semester – IX

PH553	Project Phase I	(0 – 0 – 0) 16 credits

Semester – X

PH555	Project Phase II	(0 – 0 – 0) 18 credits

PG Elective Courses

PH464 Optical Communication (3 – 0 – 0) 3 credits

Introduction to information theory- Shannon noiseless coding theorem and Shannon noisy coding theorem.

Introduction to optical communication: Overview of General communication, advantage of optical communication, review of optical fibre and its propagation characteristics, signal attenuation in fibre, dispersion, classification and effect of dispersion in information transfer, review of fibre connectors, couplers, optical filter, isolator, circulator and attenuator.

Aspects of design of optical communication: optical fibre systems, modulation schemes, Digital and analog fibre communication system, system design consideration, emitter and detector design, fibre choice, connectors, various amplifiers and its characteristics.

Optical transmitter: Basic concepts, characteristics of semiconductor injection LASER, LED, transmitter design.

Optical Receiver: Basic concepts, P-n and Pin photo detectors, Avalanche photo detectors, MSM photo detector, receiver design, receiver noise, receiver sensitivity, optical amplifier and its applications.

Coherent communication: Basic concept, detection principles, practical considerations, modulation and demodulation schemes, heterodyne and homodyne detection, single and multicarrier systems, DPSK field demonstrated system, multicarrier and network.

Introduction to Advanced optical communication:

Wavelength division multiplexing (WDM): multiplexing techniques, topologies and architectures, wavelength shifting and reverse, switching WDM demultiplexer, optical add/drop multiplexers.

Dense wavelength division multiplexing (DWDM): system considerations, multiplexers and demultiplexers.

Fiber amplifier for DWDM, SONET/SDH transmission, modulation formats, NRZ and RZ signalling, DPSK system modeling.

Text Books/References

1. Communication system - B.P Lathi
2. Optical fiber communications: Principles and practice- John M. Senior-Prentice Hall of India
3. Optical communication systems-John Grower- Prentice Hall of India
4. Optical fiber communications- Gerd Keiser-McGraw Hill, 3 ed.
5. Non-linear optics – G.P Agarwal- Academic Press
6. WDM optical networks: concepts, design and algorithms- C.Sivaram murthy and Mohan Gurusamy-Prentice Hall of India, 2002
7. Understanding SONET/SDT and ATM communication network for next millenium- Stamatios V Kartalopoulos- Prentice Hall of India, 2000
8. Elements of Information theory, T M Cover and J A Thomas, Wiley, 2006

PH465 Advanced Optoelectronics (3 – 0 – 0) 3 credits

Review of Semiconductor device Physics, Semiconductor Opto electronics- Solid State Materials, Emitters, Detectors and Amplifiers, Semiconductor Emitters- LEDs, Diodes, SLDs, CCDs, Semiconductor lasers- basic Structure, theory and device characteristics, DFB, DBR, Quantum well lasers ,Laser diode arrays, VCSEL etc. Semiconductor photo detectors:Materials - Si, Hg Cd Te, InGa As, Al Ga As, GaN etc for different wavelengths.

Detectors: Photoconductors, photo diodes, PIN, APD, Photo transistors, solar cells, CCDs, IR and UV detectors.

Band gap Engineering, Quantum well structures, size effects, Hetero and nano structures. Fabrication techniques [MBE, CVD, Lithography, Thin films technoloy] and Device characterization. Integrated Optics-Optical wave guide theory, wave guide structures. Fiber optic interconnects- Fiber lasers and amplifiers, fiber sensors.

Optoelectronic Integrated Circuits [OEIC]- Directional couplers, Dividers, Multiplexers, Phase and Amplitude Modulators, Polarization and polarization controllers, etc. Photonics Signal processing, Nonlinear optics-Frequency Converters, Phase conjugation, optical Correlation etc.

Photonic devices and applications for aerospace: Intensity, phase and polarization based Fiber optic sensors for measurement of temperature, pressure, stress etc for space craft health monitoring, Hydrogen leakage sensing in cryo engines. Fiber Optic Gyroscope for navigation application. Optical Intra Satellite links using ELED's, VCSELs. Fiber Bragg gratings for health monitoring and smart materials: applications in aerospace.

Text Books/References

1. Physics of Opto-electronic Devices- Shun Lien Chuang-Wiley, John&Sons-2009
2. Physics of Semiconductor devices-S.M.Sze & Kwok K Ng, Third edition,Wiley-2007[parts I, II and IV]
3. Infrared Photon detectors-Antoni Rogalski [Ed]-SPIE Optical Engineering Press-1995
4. CCD arrays, Cameras & Displays-Gerald C Hoist 1998 [2nd Ed], JCD Publishing-SPIE Optical Engg.Press
5. Fundamentals of Photonics, by Bahaa E. A. Saleh and Malvin Carl Teich, Wiley Series in Pure and Applied Optics
6. Photonic Devices By Jia-Ming Liu Cambridge University Press, 2005
7. Photonic Devices and Systems –by Robert G. Hunsperger, Taylor & Francis, 1994

PH467 Non-Linear Optics (3 – 0 – 0) 3 credits

Nonlinear optical susceptibility, wave equation description of nonlinear optical interactions - Sum frequency generation, Difference frequency generation, Second Harmonic generation, Phase matching condition, Optical parametric Oscillators, Quantum mechanical theory of nonlinear optical susceptibility- Schrodinger equation calculation, density matrix calculation. Spontaneous light scattering and acoustooptics, Stimulated Brillouin Scattering, Stimulated Rayleigh Scattering, Stimulated Raman Scattering, Second harmonic generation, parametric processes, 3rd order nonlinear optics, Kerr type nonlinearities, 4-wave mixing, self focusing collapse, optical breakdown, two beam coupling, electrooptics and photorefractive effects, optically induced damage and multiphoton absorption, Ultrafast and intense field nonlinear optics and optical solitons.

Text Books/References

1. Nonlinear optics, second Edition, Robert W Boyd, Academic Press (2003)
2. Photonics-Optical Electronics in Modern communications, A Yariv and P Yeh, Sixth edition, Oxford University Press (2007)
3. The Principles of nonlinear Optics, Y R Shen, Wiley-Interscience, 1991
4. Handbook of Nonlinear Optics, R L Sutherland, Marcel Dekker, 1996

PH468 MEMS and MOEMS (3 – 0 – 0) 3 credits

Introduction: Fourier Optics, Holography, Optical thin films and periodical structures Bragg gratings, photonic crystals, Gaussian beam propagation, ultra fast lasers, Fundamentals of Nonlinear Optics, Quantum optics.

MEMS: Introduction & applications, Substrates: Quartz, Ceramics, and Polymers.

Smart materials and their properties. Thin films in the context of smart materials, nano, & micro-technologies. Lithography: Fundamentals. Materials such as photoresist used in lithography. Techniques such as using optical, electron beam,focused ion,x-ray beams. Etching and micro machining. Wet and dry etching, deep reactive ion etching. Packaging and bonding, micro-assembly. Reliability studies in packaging.

MEMS devices for applications such as in aerospace, biomedical and process industries.

MOEMS: MOEM overview, MOEM scanners, MOEM technology and applications to telecom, CMOS compatible MOEMS, optics specific issues for MOEMS, micro-optics, automation and sensing, shape memory actuators, piezoelectric actuators, magnetic actuators, MOEMS related sensors, micro-optic components, testing and applications**.**

Text Books/References

1. Nodium Maluf, “An introduction to micromechanical systems engineering”
2. Marc Madou, “Fundamentals of micro fabrication” CRC press (1997).
3. Ristic (Ed) “Sensor Technology & Devices”, Artech House Publications (1994).
4. MOEMS, SPIE Press, USA

PH469 Laser Applications (3 – 0 – 0) 3 credits

Laser for detection and ranging- LIDAR applications-Doppler wind LIDAR, Differential Absorption LIDAR for water vapor monitoring. Laser application in material processing – esp. CO_2, YAG , Excimer,Ruby lasers- [material processing, Cutting, Welding, drilling, micro machining] – Interation of laser radiation with matter, Heat Flow Theory, Process characteristics etc. Laser anemometry, Schlieren Techniques for wind tunnels, Holography etc Lasers for metrology – Interferometery for surface characterization, precision length measurement, time standards etc, Medical applications of laser.

Lasers for space applications – free space communication, laser propulsion, laser ignition,Optical Rotation sensors and their applications for space navigation: Sagnac Interferometers and their applications for space, Fiber Optic Gyros –Fibers, Guided Wave optics, Sources and detectors for Fiber Optic Sensors, Fiber optic couplers, modulators etc, Closed and open loop Fiber optic gyros – configurations, design and application for space navigation, Fiber optic acceleration sensors. Ring Laser gyros- Laser Resonator Design, Laser Frequency stabilization techniques, Ring resonator – stable and unstable and their application in Ring Laser Gyros, Fabrication and metrology of precision laser optics. Ultra High vacuum [production, measurement] techniques relevant to Gas laser processing. Optical gyros error modeling, error compensation, test methodologies and applications for inertial navigation.

Text Books/References

1. Quantum Elecrtronics, Amnon Yariv, John Wiley [1989]
2. Lasers, Siegman, Anthony E California/University of Science Books/1986
3. Physics of gas lasers, Bennett, W R/Montroll, Elliot W, New York/Gordon and Breach/1977
4. Introduction to gas lasers : Population inversion mechanisms, Willett, Colin S/Haar, D Ter, Oxford/Pergamon press/1974
5. Laser resonators and beam propagation, Hodgson, Norman/Weber, Horst New York/Springer Science/2005, Springer series in optical sciences
6. Physics and technology of laser resonators. HALL, Denis R/JACKSON, Paul E Bristol/Adam Hilger/1989,
7. Laser gyros and fibre optic gyros : Proceedings, London/Royal aeronautical society/1987.
8. Ring laser gyro (RLG) technology, Filatov, Yuri Chennai/1999
9. Laser applications,V.1, ROSS, monte, New York/Academic Press
10. Engineering applications of lasers and holography, Kock, Winston E/WOLFE William L New York/Plenum press/1975
11. Fiber-optic gyroscope, Lefevre, Herve, Boston/Arcteh House/1993

PH470 Quantum Optical Communication (3 – 0 – 0) 3 credits

Quantum theory of light: quantization of the electromagnetic field, evolution of the field operators, quantum states of the electromagnetic field. Quantum information processing: quantum information, quantum communication, quantum computation with qubits, quantum computation with continuous variables. Density operators and super operators, fidelity, entropy, information and entanglement measures, correlation functions and interference of light, photon correlation measurements. Photon sources and detectors: Mathematical model of photodetectors, physical implementations of photodetectors, single-photon sources, entangled photon sources, quantum non-demolition photon detectors. Quantum communication with single photons: photons as information carriers, quantum teleportation and entanglement swapping, decoherence-free subspaces for communication, quantum cryptography. Quantum computation with single photons. Quantum communication with continuous variables: phase space in quantum optics, continuous-variable entanglement, teleportation and entanglement swapping, entanglement distillation, quantum cryptography. Quantum computation with continuous variables. An ensemble of identical two-level atoms, electromagnetically induced transparency, quantum memories and quantum repeaters, the atomic ensemble of a single qubit, photon-photon interactions via atomic ensembles, Solid-state quantum information carriers: Definition and optical manipulation of solid-state qubits, interactions in solid-state qubit systems, entangling two-qubit operations, scalability of solid-state devices.

Text Books/References

1. P. Kok and B. W. Lovett, Introduction to Optical Quantum Information Processing, Cambridge university press.
2. L. Mandel, and E. Wolf. Optical Coherence and Quantum Optics, Cambridge University Press.
3. W. H. Louisell, Quantum Statistical Properties of Radiation, McGraw-Hill.
4. D. Bouwmeester, A. K. Ekert, and A. Zeilinger, eds. The Physics of Quantum Information, Springer

PH472 Quantum Many-Body Physics (3 – 1 – 0) 4 credits

Second quantization: Fock space representation, creation and annihilation operators for bosons and fermions, representation of many-body operators.

Green's functions at zero temperature: Interaction representation, Wick's theorem, Feynman diagrams.

Finite temperatures: Matsubara functions, retarded and advanced Green's functions. Linear response, Kubo formula.

Interacting fermions: Fermi liquid theory, Hubbard model, Heisenberg model.

Electron-Phonon interaction, BCS theory of superconductivity.

Text Books/References

1. A. Altland and B. Simmons, Condensed Matter Field Theory.
2. G. D. Mahan, Many-Particle Physics.
3. J. W. Negele and H. Orland, Quantum Many-Particle Systems

PH473 Device Physics and Nanoelectronics (3 – 0 – 0) 3 credits

Introduction: Moore’s law and technology development. International Technology Roadmap for Semiconductors (ITRS); Technology and material challenges limiting Moore’s law.

Contacts: Fabrication of Junction, Metal-semiconductor contacts, Schottky barrier. Contact resistance: 2-probe and 4-probe measurements; Kelvin and van der Pau structures; pn junctions: carrier transport. Equilibrium conditions, Steady state conditions, Transients and AC conditions.

MOS devices: Oxide charges and band-bending, Capacitance – Voltage (C-V) behavior of pMOS and nMOS devices, dissipation factor, band-diagram and degeneracy at accumulation and inversion, depletion width, Mott-Schottky plot and carrier concentration. Frequency dispersion of capacitance, correction of high-frequency capacitance, interface states, parallel conductance measurements, Equivalent oxide thickness (EOT); Leakage current mechanisms through MOS devices – space charges and Child's law, Schottky emission, direct tunneling, band diagram under external field: Fowler-Nordheim tunneling, Poole- Frenkel charge injection.

MOSFET devices: Process technology of fabricating a MOSFET, degenerate states of inversion and formation of the channel, Operation of a MOSFET: Output characteristics: conduction through the channel at low fields; linear regime and Ohm's law: surface mobility and bulk mobility of charges in a semiconductor. Factors influencing the mobility and mobility saturation; pinch-off and drain-current saturation; Threshold voltage of a MOSFET, Sub-threshold conduction in a MOSFET, transfer characteristics, transconductance and subthreshold swing, cutoff frequency. The Non-ideal MOSFET behavior: effects of Shottky contacts, influence of the oxide charges.

MOSFET scaling: scaling roadmap, Short-channel effects: Short-channel effect in transfer and output characteristics.

Introduction to Nanoelectronics: Single molecule field effect transistors, Nanowire FET's, Single electron transistors, Single electron tunneling (SET) devices: Coulomb blockade phenomenon. Nano-scale flash memory devices – Yano memory devices, Resonant tunneling devices (RTD).

Optoelectronics devices: Photodiodes, Light emitting diodes, semiconductor lasers.

Text Books/References

1. S.M. Sze, Physics of Semiconductor Devices, Wiley Publications.
2. Supriyo Dutta, Electronic Transport in Mesoscopic Systems, Cambridge University Press.
3. D. K. Schroder, Semiconductor material and Device Characterization, Wiley Interscience.
4. Nicollian and Brews, Metal-Oxide-Semiconductor (MOS) Physics and Technology, Wiley Interscience.

PH474 Atomic and Molecular Spectroscopy (3 – 0 – 0) 3 credits

Atomic structure and spectroscopy: One and multi electron atoms, energy level notation schemes, interaction of electromagnetic radiation with atoms, Einstein's coefficients, line shape and broadening. Visible, UV and x-ray spectroscopy of atoms. Instrumentation and applications. Astronomical significance.

Molecular spectroscopy: Molecular structure, Group theory for molecular physics, Huckel model, Hartree Fock, density functional calculation of di-atomic and poly-atomic molecules. Energy level structure and notation, electronics, vibrational and rotational structure. Visible, IR and microwave spectroscopy. Raman spectroscopy and its applications.

Resonance spectroscopy: Electron spin resonance, nuclear magnetic resonance, Mganetic Resonance Imaging. Mossbauer spectroscopy.

Mass spectroscopy: Mass spectrometer basics, instrumentation, ion traps as mass spectrometers, Paul and Penning traps, multipole traps. Fourier transform infrared spectroscopy.

Cold atoms: Cooling of atoms, techniques, laser cooling, magneto optical traps, BEC, spectroscopy in condensates, frequency standards.

Text Books/References

1. Fundamentals of Molecular Spectroscopy By Banwell (4^{th} edition, TMH)
2. Atomic and molecular spectroscopy: basic aspects and practical applications By Sune Svanberg (4^{th} edition, Springer)
3. Modern spectroscopy By John Michael Hollas (4^{th} edition, Wiley)
4. Quadrupole ion trap mass spectrometry By Raymond E. March, John F. J. Todd (2^{nd} edition Wiley inter science)

5. Mass spectrometry: principles and applications By Edmond de Hoffmann, Vincent Stroobant (3rd edition, Wiley)
6. Mass spectrometry: instrumentation, interpretation, and applications By Rolf Ekman (Wiley interscience)
7. Charged particle traps Volume 1 By Fouad G. Major, Viorica N. Gheorghe, Günter Werth (Springer)
8. Physics of atoms and molecules By B. H. Bransden, Charles Jean Joachain (2nd edition Prentice Hall)

PH475 Cold Atoms and Bose-Einstein Condensates (3 – 0 – 0) 3 credits

Atomic gases, Collisions and trapping, Interaction with the radiation filed and optical traps, Light forces on atoms, Doppler and sub-Doppler cooling, Magneto-Optical Trap, evaporate cooling, Optical Lattices, Ion traps, experiments on cold atoms.

The Ideal Bose gas, Weakly-interacting Bose gas, Ground state energy and equation of state, Particles and elementary excitations. Nonuniform Bose gases at zero temperature, Gross-Pitaevskii equation, Thomas-Fermi limit, solitons, quantization and elementary excitations.

The ideal Bose gas in the harmonic trap, condensate fraction and critical temperature, density and momentum distribution, Ground state of a trapped condensate, Dynamics of a trapped condensate, Bose-Einstein condensate in optical lattices.

Text Books/References

1. L. Pitaevskii and S. Stringari, Bose-Einstein Condensation, Oxford (2003).
2. C.J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases, Cambridge (2008).
3. Christopher J. Foot, Atomic Physics, Oxford (2005).

PH476 Principles of Magnetic Resonance (3 – 0 – 0) 3 credits

Elements of Resonance: Introduction, Simple resonance theory, Absorption of energy and spin-lattice relaxation.

Basic theory: Motion of isolated spins – Classical treatment, Quantum mechanical description of spin in a static field, Equations of motion of the expectation value, Effect of Alternating Magnetic Fields, Exponential Operators, Quantum mechanical treatment of a rotting magnetic field, Bloch equations, Solution of the Bloch equations for low H1, Spin Echoes, Quantum mechanical treatment of the spin echo.

Magnetic dipolar broadening of Rigid Lattices: Introduction, Basic Interaction, Method of moments, Examples of the use of second moments.

Magnetic interaction of nuclei with electrons: Introduction, Experimental facts about chemical shifts, Quenching of orbital motion, Formal theory of chemical shifts, Electron spin interaction, Single Crystal, Second order spin effects – indirect nuclear coupling.

Pulsed and Fourier Transform NMR: Introduction, Density matrix – general equations, The rotating coordinate transformation, Spin echoes using the density matrix, Response to a delta – function, Response to a □/2 pulse, Density matrix of a two level system, Effect of applied alternating fields, Two dimensional Fourier Transform – the basic concept, Two dimensional Fourier Transform spectrum- line shapes, Time development of the density matrix, coherence transfer, The product operator approach in NMR, Shift Correlation Experiment (COSY). Double Resonance – principles, The Insensitive Nuclei Enhancement by Polarization Transfer (INEPT), The hetero-nuclear Single Quantum coherence (HSQC).

Text Books/References

1. C. P. Slichter; Principles of Magnetic Resonance, Springer Series.
2. A. Abragam; Principles of Nuclear Magnetism, Oxford University Press.

3. Ray Freeman, Spin Choreography- Basic steps in high Resolution NMR, University Sciences Book
4. M. H. Levitt; Spin Dynamics-Basics of Nuclear Magnetic Resonance, Wiley

PH477 High Resolution NMR Spectroscopy in Solids (3 – 0 – 0) 3 credits

Nuclear spin interactions in solids: Basic nuclear spin interactions in solids, spin interactions in high magnetic fields, transformation properties of spin interactions in real space, powder spectrum ilne shapes, specimen rotation, rapid anisotropic molecular rotation, ine shapes in the presence of molecular reorientation.

Multiple-pulse NMR experiments: Idealized multiple-pulse sequences, the four-pulse sequence (WHH4), coherent averaging theory, application of coherent averaging theory to multiple-pulse sequences, arbitrary rotations in multiple-pulse experiments, resolution fo multiple-pulse experiments, magic angle rotating frame line narrowing experiments.

Double resonance experiments: Basic principles of double resonance experiments, cross-polarization of dilute spins, cross-polarization dynamics, spin decoupling dynamics.

Magnetic shielding tensor: Ramsey's formula, approximate calculations of the shielding tensor, photon shielding tensors, I3C shielding tensors.

Spin-Lattice relaxation in iine narrowing experiments: Spin-lattice relaxation in multiple-pulse experiments, application of multiple-pulse experiments to the investigation of spin-lattice relaxation, spin-lattice relaxation in dilute spin systems.

Text Books/References

1. M. Mehring, High Resolution NMR Spectroscopy in Soilds, Springer-Verlag, 1976.

PH478 Solid State NMR Spectroscopy (3 – 0 – 0) 3 credits

Theory of solid state NMR and its experiments: The basics of solid state NMR, the vector model of pulsed NMR, the quantum mechanical picture: Hamiltonians and the Schrodinger equation, the density matrix representation and coherences nuclear spin interactions, calculating NMR power patterns, general features of NMR experiments.

Essential techniques for spin–1/2 nuclei: Introduction, magic-angle spinning (MAS), high-power decoupling, multiple pulse decoupling sequences, average Hamiltonian theory and the toggling frame, cross-polarization, solid or quadrupole echo pulse sequence.

Dipolar coupling, its measurement and uses: Introduction, techniques for measuring homonuclear dipolar couplings, recoupling pulse sequences, double-quantum filtered experiments, rotational resonance, techniques for measuring heteronuclear dipolar couplings, spin-echo double resonance, rotational-echo double resonance, techniques for dipolar-coupled quadrupolar (spin–1/2) pairs, transfer of population in double resonance, rotational echo, adiabatic passage, double resonance, techniques for measuring dipolar couplings between quadrupolar nuclei, correlation experiments, homonuclear correlation experiments for spin–1/2 systems, homonuclear correlation experiments for quadrupolar spin systems, heteronuclear correlation experiments for spin–1/2, spin-counting experiments, the formation of multiple-quantum coherences, implementation of spin-counting experiments.

Quadrupole coupling, its measurement and uses: The quadrupole Hamiltonian, the effect of RF pulses, high-resolution NMR experiments for half-integer quadrupolar nuclei, magic-angle spinning, double rotation, dynamic-angle spinning, multiple-quantum magic-angle spinning, other techniques for half-integer quadrupolar nuclei, quadrupole nutation.

Shielding and chemical shift: The relationship between the shielding tensor and electronic structure, measuring chemical shift anisotropies, magic-angle spinning with recoupling pulse sequences, variable angle spinning experiments, magic-angle turning, two-dimensional separation of spinning sideband patterns.

Text Books/References

1. M. J. Duer, Solid State NMR Spectroscopy: Principles and Applications, Blackwell Science Ltd.

PH479 Solid State NMR Spectroscopy (3 – 0 – 0) 3 credits

Solid state NMR studies in condensed matter liquid-crystalline materials: The liquid-crystalline state, orientational order phase symmetry, molecular orientational order, the general time-independent NMR Hamiltonian for liquid crystalline samples, molecular order parameters, different representations of the order parameters, molecular order parameters and the symmetry of rigid molecules, director alignment, dipolar couplings between nuclei in rigid molecules in liquid-crystallline phases, deuterium quadrupolar splittings for rigid molecules in liquid-crystalline phases, chemical shift anisotropy for rigid molecules in liquid-crystalline phases, electron-mediated spin-spin coupling in liquid-crystalline samples, the determination of the structure, orientational order and conformations of flexible molecules in liquid-crystalline sample, determination of the conformationally dependent orientational order parameters and the conformational distributions of molecules in liquid-crystalline phases from NMR parameters, NMR experiments for liquid-crystalline samples, spectra of chiral and prochiral molecules in chiral liquid crystalline phases.

NMR studies of oxide glass structure: Introduction, the 'structure' of a glass, the extent of disorder, liquids vs. glasses, NMR techniques for studying glass structure, techniques for observing 1H and 19F in glasses, techniques that eliminate second-order quadrupolar broadening (DOR, DAS, MQMAS), spin-lattice relaxation and structure, applications to specific glass systems, boron-containing oxide glasses, silicate, aluminosilicate and germanate glasses, hydrogen-containing species in oxide glasses, thermal history effects, long-range structural anisotropy.

Text Books/References

1. P. J. Collings and M. Hird, Introduction to Liquid Crystals, Taylor & Francis, London.
2. D. Demus, J. W. Goodby, G. W. Gray, H. Spiess, and V. Vill (Eds.), Handbook of Liquid Crystals, Springer-Verlag.
3. P. J. Bray and M. L. Liu, in G. E. Walrafen and A. G. Revesz (Eds.), Structure and Bonding in Noncrystalling Solids, Plennum Press, New York (1986), p. 285.
4. R. Dupree, S. C. Kohn, M. G. Mortuza, and D. Holland, in L. D. Pye, W. C. La Course and H. J. Stevens (Eds.), Physics of Non-Crystalling Solids, Taylor & Francis, London (1992), p. 718.