Indian Institute of Space Science and Technology

Department of Space, Govt. of India

Thiruvananthapuram

Dual Degree Programme

Bachelor of Technology in Engineering Physics with

Master of Science in Astronomy & Astrophysics or

Master of Technology in Earth System Science or

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
AV111	Basic Electrical Engineering	3	0	0	3
HS111	Communication Skills	2	0	3	3
PH131	Physics Lab	0	0	3	1
AE131	Basic Engineering Lab	0	0	3	1
	Total	16	3	9	22

Semester – II

Code	Title	L	T	P	C
MA121	Vector Calculus and Differential Equations	2	1	0	3
MA122	Computer Programming and Applications	2	0	3	3
PH121	Physics II	3	1	0	4
CH121	Material Science and Metallurgy	3	0	0	3
AV121	Basic Electronics Engineering	3	0	0	3
AE141	Engineering Graphics	1	0	3	2
CH141	Chemistry Lab	0	0	3	1
AV141	Basic Electrical and Electronics Engineering Lab	0	0	3	1
	Total	14	2	12	20

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
AE216	Thermodynamics	3	0	0	3
AV215	Signals and Systems	3	1	0	4
HS211	Introduction to Economics	2	0	0	2
PH231	Optics Lab I	0	0	3	1
	Total	17	1	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	Classical Mechanics	3	1	0	4
AE225	Fluid Dynamics	3	0	0	3
AV225	Analog and Digital Circuits	3	0	0	3
HS221	Introduction to Social Science and Ethics	2	0	0	2
PH241	Optics Lab II	0	0	3	1
	Total	17	1	3	19

Semester – V

Code	Title	L	T	P	C
MA311	Probability, Statistics, and Numerical Methods	3	0	0	3
PH311	Quantum Mechanics	3	1	0	4
PH312	Statistical Mechanics	3	0	0	3
AV316	Digital Signal Processing	3	0	0	3
AV317	Instrumentation and Measurement	3	0	0	3
HS311	Principles of Management Systems	3	0	0	3
PH331	Modern Physics Lab	0	0	3	1
AV336	Digital Signal Processing Lab	0	0	3	1
AV337	Instrumentation and Measurement Lab	0	0	3	1
	Total	18	1	9	22

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 Courses

Code	Title	L	T	P	C
AV361	Database Management Systems	3	0	0	3
AV362	Computer Architecture	3	0	0	3

Elective 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

Master of Science in Astronomy & Astrophysics

Semester – VII

Code	Title	L	T	P	C
ESA411	Astronomical Techniques	3	0	0	3
ESA412	Radiation Processes in Astrophysics	3	0	0	3
ESA413	Planetary Sciences	3	0	0	3
ESA414	Computational Astrophysics	2	0	6	4
E03	Institute/Department Elective	3	0	0	3
ESA431	Data Analysis Astronomy Lab	0	0	3	1
PH452	Summer Internship and Training	0	0	0	3
	Total	14	0	6	20

Semester – VIII

Code	Title	L	T	P	C
ESA421	Structure and Evolution of Stars	3	0	0	3
ESA422	Galaxies (Structure, Dynamics and Evolution)	3	0	0	3
ESA423	Cosmology	3	0	0	3
ESA4xx	PG Elective I	3	0	0	3
ESA441	Observational Astronomy Lab	0	0	6	2
ESA451	Seminar I	0	0	0	2
ESA452	Comprehensive Viva-Voce II	0	0	0	2
	Total	12	0	3	18

Semester – IX

Code	Title	L	T	P	C
ESA551	Seminar II	0	0	0	2
ESA552	Thesis Phase I	0	0	0	16
	Total	0	0	0	18

Semester – X

Code	Title	L	T	P	C
ESA553	Thesis Phase II	0	0	0	17
	Total	0	0	0	17

Semester-wise credits

Semester	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Credits	22	20	20	19	22	21	20	18	18	17	197

List of PG Electives

Code	Title	L	T	P	C
ESA461	Gas Dynamics	3	0	0	3
ESA462	Physics of Interstellar and Intergalactic Medium	3	0	0	3
ESA463	High Energy Astrophysics	3	0	0	3
ESA464	Estimation and Stochastic Processes	3	0	0	3
ESA465	Formation of Stars and Planets	3	0	0	3
ESA466	Advanced Astronomical Imaging	3	0	0	3
ESA467	Radiation Hydrodynamics	3	0	0	3
ESA468	Accretion Physics	3	0	0	3
ESA469	High Redshift Universe	3	0	0	3
ESA470	Polarization in Astronomy	3	0	0	3
ESA471	High Resolution Spectroscopy	3	0	0	3
ESA472	Time Domain Astronomy	3	0	0	3
ESA473	Exoplanets and Astrobiology	3	0	0	3
ESA475	Physics of the Sun	3	0	0	3

Dual Degree Earth System Science

Curriculum

Semester VII:

Code	Course Title	L	T	P	C
ESE 411	Dynamics of Atmosphere	3	0	0	3
ESE 412	Physical and Dynamical Oceanography	3	0	0	3
ESE 413	Earth Resources and Tectonic Systems	3	0	0	3
ESE 414	Radiation Processes in Atmosphere	3	0	0	3
ESE 415	Atmospheric Thermodynamics and Cloud Physics	3	0	0	3
ESE 431	Observational Technique (Lab)	0	0	3	1
ESE 432	Geology (Lab)	0	0	3	1
PH 452	Summer Internship and Training	0	0	0	3

Semester VIII:

Code	Course Title	L	T	P	C
ESE 4XX	Elective I	3	0	0	3
ESE 4XX	Elective II	3	0	0	3
ESE 4XX	Elective III	3	0	0	3
ESE 4XX	Elective IV	3	0	0	3
ESE 4XX	Elective V	3	0	0	3
ESE 441	Lab I	0	0	3	1
ESE 442	Lab II	0	0	3	1
ESE 451	Seminar	0	0	0	2

Semester IX:

Code	Course Title	L	T	P	C
ESE 552	Project (Midterm + Phase I)	0	0	0	14

Semester X:

Code	Course Title	L	T	P	C
ESE 553	Project (Midterm + Phase II + Thesis)	0	0	0	18
ESE 554	Comprehensive viva-voce	0	0	0	2

Electives:

Code	Course Title	L	T	P	C
ESE 461	Planetary Atmospheres	3	0	0	3
ESE 462	Numerical Weather Prediction	3	0	0	3
ESE 463	Planetary Geosciences	3	0	0	3
ESE 464	Aerosol-Cloud-Climate Interaction	3	0	0	3
ESE 465	Air-Sea Interaction	3	0	0	3
ESE 466	Satellite Meteorology and Oceanography	3	0	0	3
ESE 467	Boundary Layer Meteorology	3	0	0	3
ESE 468	Polar Science	3	0	0	3
ESE 469	Ionosphere and Space Physics	3	0	0	3
ESE 470	General Circulation and Monsoon	3	0	0	3
ESE 471	Land – Atmosphere Interaction Dynamics	3	0	0	3
ESE 472	Atmospheric and Oceanic Instrumentation and Measurement Techniques	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	Guided Wave Optics	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	19	22	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	Optical Communication	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

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	3	4
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	12	2	9	22

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	14	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	19	22	21	22	18	16	18	198

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, 5th ed., Brooks/Cole (2007).
2. Jain, R. K. and Iyengar, S. R. K., Advanced Engineering Mathematics, 4th 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, 9th ed., John Wiley (2005).
4. Thomas, G. B. and Finney, R. L., Calculus and Analytic Geometry, 9th ed., Pearson Education (2003).

PH111	Physics I	(3 – 1 – 0) 4 credits

Vectors, Statics, and Kinematics: introduction to vectors (linear independence, completeness,basis, dimensionality), inner products, orthogonality – principles of statics, system of forces in plane and space, conditions of equilibrium – displacement, derivatives of a vector, velocity, acceleration – kinematic equations – motion in plane polar coordinates.

Newtonian Mechanics: momentum, force, Newton's laws, applications – conservation of momentum, impulse, center of mass.

Work and Energy: integration of the equation of motion – work energy theorem, applications – gradient operator – potential energy and force - interpretation – energy diagrams – law of conservation of energy – power – particle collisions.

Rotations: angular momentum – torque on a single particle – moment of inertia – angular momentum of a system of particles – angular momentum of a rotating rigid body.

Central Force 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 Kepler's laws.

Harmonic Oscillator: 1-D harmonic oscillator – damped and forced harmonic oscillators.

Modern Physics: relativity – introduction to quantum physics – atom model – hydrogen atom.

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, 2^{nd} ed., Wiley (1986).
4. Sadiku, M. N. O., Elements of Electromagnetics, 8^{th} 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, 7^{th} ed., John Wiley (2007).
2. Raghavan V., Physical Metallurgy: Principles and Practice, 2^{nd} ed., Prentice Hall (2006).

References

1. Billmeyer, F. W., Textbook of Polymer Science, 3^{rd} ed., Wiley India (1984).
2. Askeland, D. R. and Phule, P. P., The Science and Engineering of Materials, 4^{th} 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 eqaution – 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, guage transformations – Coulumb 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; Relativitistic 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

Curvilinear Co-ordinates and Matrices, Orthogonal coordinates, cylindrical coordinate systems, Spherical polar coordinate systems, orthogonal matrices, Hermiatian matrices and unitary matrices – properties.

Groups and their representations – Discrete groups, Lie groups and Lie algebra and applications – connection to rotation group, SO(3), SU(2) and the Lie algebra correspondance.

Vector spaces, Tensors, function spaces, Hilbert spaces, orthogonal expansions, operators in infinite dimensional spaces.

Fourier Series and Fourier Transform, Properties, advantages and uses of Fourier series, applications – as a method of solving common ODEs in physics.

Gibbs phenomenon, discrete Fourier Transform, transform theorems, momentum representation.

Functions, Dirac-Delta function, Legendre functions, Bessel Functions, Laguerre functions, Hermite functions – applications of heat conduction problem, diffusion problem, Laplace equation and Poisson equation with different boundary conditions.

Text Books

1. E. Butkov, Mathematical Physics, Addison Wesley, 1973
2. G. B. Arfken and H. J. Weber, Mathematical methods in physics, Academic Press, 2001

References

Same as Text Books

AE216 Thermodynamics (3 – 0 – 0) 3 credits

Thermodynamic system and state variables, zeroth law; 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; availability; properties of pure fluids, Maxwell's relations, evaluation of thermodynamic properties; thermodynamic properties of gas mixtures.

Text Books

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 – Textbook with Tables Booklet, Academic Press (2010).
3. Annamalai, K., I. K. Puri, and M. A. Jog, Advanced Thermodynamics Engineering, CRC Press (2010).

AV215 Signals and Systems (3 – 1 – 0) 4 credits

Classification of signals and systems, Types of signals, Types of systems, Analysis of Continuous Time Signals and LTI systems: Fourier series, Fourier Transform, Laplace Transform, Differential Equation, State Space Matrix, Anlaysis of Discrete Time Signals and LTI DT systems: Fourier Transform, DFT, Z Transform, wavelet transform,Difference Equations, State variable equation and matrix, some applications –

communication, control systems etc.

Text Books

1. B.P. Lathi, Linear Systems and signals, 2nd edition, Oxford University Press, 1998.
2. A.V. Oppenheim, A.S. Willsky and I.T. Young, Signals and Systems, Prentice Hall, 2006.

References

1. Simon Haykin, Barry Van Veen, Signals and Systems, John Wiley and Sons (Asia) Private Limited, 2005.
2. R.F. Ziemer, W.H. Tranter and D.R. Fannin, Signals and Systems – Continuous and Discrete, Prentice Hall, 2006.

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

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

Rigorous diffraction theory, diffraction of a Gaussian beam, applications of Fresnel and Fraunhofer diffraction, Fourier optics, Fourier transforming property of a thin lens, spatial frequency filtering and its applications, OTF, MTF.

Coherence theory, partial coherence, holography, construction and reconstruction of hologram.

Light quanta and their origin, thermal equilibrium of radiation, Einstein's coefficients, metastable states, population inversion, optical pumping, spontaneous and stimulated emission, Lasers - working principle, threshold condition for lasing, resonant cavities, two-level and three-level lasers, Ruby, He-Ne, carbon dioxide lasers.

Theory of optical fibers and wave guides, scalar wave equation, modes of a fiber and planar wave guides, periodic media, Bragg diffraction and Bragg devices.

Elements of non-linear optics, higher harmonic generation, optical phase conjugation, optical bistability, solitons, self and cross phase modulations, optical Bloch equation, Stimulated Raman Scattering.

Electro-optic effects in different crystals, acousto-optic effects, Raman-Nath diffraction and acousto-optic devices.

Text Books

1. Ghatak, A. K. and Thyagarajan, K – Optical Electronics, Cambridge University Press, 2009.
2. Born. M and E. Wolf, Principles of Optics, Seventh edition, Cambridge University Press, 2006.
3. Baha E. A., Saleh and M. C. Teich - Fundamentals of Photonics, John Wiley and Sons, 1991.
4. Goodman, J. W - Introduction to Fourier Optics, Third Edition, Viva Books Private Limited, 2007.
5. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press, 2003.
6. Keiser, G - Optical Fiber Communications, Fourth Edition, Tata McGraw Hill, 2008.
7. Laud, B.B. - Lasers and Nonlinear Optics, New Age International (P) Limited, 1991.

References

Same as Text Books

PH222	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.

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, 6th 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).

AV225	Analog and Digital Circuits	(3 – 0 – 0) 3 credits

Analog Electronics: BJT Amplifiers and its frequency response characteristics, Feedback amplifiers, Linear and Nonlinear Circuits using operational amplifiers and their analysis -Differential Amplifier, Instrumental amplifiers, Oscillators, Multivibrators, Timers, PLL, A/D converters.

Digital Electronics: Logic families, Design of combinational circuits, Programmable Logic Devices asynchronous and synchronous sequential circuits, Memories.

Text Books

1. Electronics Devices and Circuit Theory, Robert Boylestad, Louis Nashelsky, PHI, 10th edition
2. Sergio Franco, 'Design with operational amplifiers and analog integrated circuits', McGraw-Hill, 1997.
3. Morris Mano, Digital Design, 4th ed., Prentice-Hall of India, 2006.

References

1. William D.Stanely, 'Operational Amplifiers with Linear Integrated Circuits' Pearson Education, 2004.
2. Ramakant A.Gayakwad, 'OP-AMP and Linear IC's', Prentice Hall / Pearson Education, 1994
3. J. Millman and C.C. Halkias, Integrated Electronics - Analog and Digital circuit system, McGraw Hill, 1996.
4. Charles H.Roth. Fundamentals of Logic Design, Thomson Learning, 5th edition
5. John F.Wakerly, Digital Design, Fourth Edition, Pearson/PHI, 2006.

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

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

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

Preliminary concepts, probability theory, random walk problem, Laws of thermodynamics and their consequences.

Phase space, Liouville's theorem and its consequences, Statistical description of system of particles, microstates, ensembles, basic postulates, density of state for ideal gas in classical limit, thermal and mechanical interactions, quasi-static process.

Microcanonical ensembles and their equivalence, canonical ensembles, partition functions, ideal gas, Gibbs paradox, equipartition theorem, M-B gas velocity and speed distribution, chemical potential, free energy and connection with thermodynamic variables, 1st and 2nd order phase transition.

Thermodynamics of black body radiation, Stefan-Boltzmann law, Wien's displacement law, Einstein and Debye's theories of specific heat of solids.

Identical particles, Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac statistics. Ideal Bose gas, Bose-Einstein condensation. Ideal Fermi gas. Ideal gases in the classical limit.

Formulation of quantum statistics, density matrix, ensembles in quantum statistical mechanics, simple application of density matrix.

Text Books

Same as Reference.

References

1. F. Reif, Fundamentals of Statistical and Thermal Physics, Levant Books.
2. R. K. Pathria, Statistical Mechanics, Pergamon Press, Oxford.
3. K. Huang, Statistical Mechanics, 2nd edition, John Wiley.

AV316 Digital Signal Processing (3 – 0 – 0) 3 credits

Basic elements of DSP, concepts of frequency in Analog and Digital Signals, Sampling theorem, Discrete time signals and systems- DFS, DTFT, DFT – FFT computations using DIT and DIF algorithms, Infinite Impuse Response Digital Filters, Finite Impulse Response Digital filters, Finite Word length effect, Introduction to Multirate Signal Processing, Applications in multirate signal processing.

Text Books

1. John G Proakis, Dimtris G Manolakis, Digital Signal Processing Principles, Algorithms and Application, PHI, 4th Edition.
2. Alan V. Oppenheim, Ronald W. Schafer & Hohn. R.Back, "Discrete Time Signal Processing", Pearson Education, 3rd edition.

References

1. Sanjay K. Mitra, Digital signal Processing – Computer Based Approach TMH, 4th edition.
2. Emmanuel C. Ifeachor, & Barrie. W. Jervis, "Digital Signal Processing", 2nd edition, Pearson Education/Prentice Hall, 2002.

AV317 Instrumentation and Measurement (3 – 0 – 0) 3 credits

Introduction to measurement, units and standards, error analysis, static and dynamic performance characteristics of instruments. Digital Measurement systems (Timer counter, DMM, A/D and D/A converters), Data Acquisition Systems, Oscilloscopes, spectrum analyzer, Null balance methods, dc and ac potentiometers, dc and ac bridges; Earth resistance measurement. Voltage and current scaling (CTs and PTs);

Instrumentation amplifiers. Transducers - strain gauges, inductive and capacitive transducers, piezoelectric and Hall-effect transducers, Temperature sensors, photo-diodes & transistors, digital transducers, signal conditioning and telemetry, introduction to smart sensors and MEMS.

Text Books

1. A.K. Sawhney, A course in Electrical and Electronics Measurements and Instrumentation, Dhanpat Rai and Sons, New Delhi, 2006.

References

1. Doebelin, E.O., Measurement systems: Application and Design, 5th ed., McGraw hill, 2003.
2. Golding E.W. and Widdis F.E., Electrical measurements and measuring instruments, Sir Issac Pitman and Sons pvt ltd, 1995.
3. Albert D. Helfrick, William D. Cooper, Modern Electronic Instrumentation and Measurement Techniques., Prentice Hall of India Private Limited.

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 – 3) 1 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

Text Books

Lab Manual

AV336	Digital Signal Processing Lab	(0 – 0 – 1)	1 credit

- Study of DFT
- IIR Filter Design
- FIR Filter Design
- FIR Kaiser and Equiripple Filter Design
- Comparison of FIR and IIR Filter Design
- Study of Simulink and Signal Processing Tool Box
- Multirate Signal processing
- DSP Processor,TMS 320C6713,DSK Experiments
- TMS 320C6713-Real Time Processing

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

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; Crystal structures: basis, crystal class, point group and space group; 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 bands; Band gap; Number of states in a band; Tight binding method; Effective mass of an electron in a band: concept of holes; Energy band in one dimension, reduced zone scheme; E-k diagram in three dimensions, band structures and energy gap; Classification of metal, semiconductor and insulator; 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; Optical properties of ionic crystal in the infrared region; 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; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, ferromagnetic domains; Ferrimagnetism and antiferromagnetism; Magnetic resonances.

Superconductivity: Phenomenological description of superconductivity, London theory, thermal conductivity and specific heat, occurrence of superconductivity, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect.

Text books:

1. Charles Kittel, Introduction to Solid State Physics, Wiley.
2. N. Ashcroft and D. Mermin, Solid State Physics, Cengage.

References:

Same as text books

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, 2nd 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 Courses

AV361	Database Management Systems	(3 – 0 – 0) 3 credits

Introduction: Purpose of Database System – Views of data – Data Models – Database Languages —Database System Architecture – Database users and Administrator – Entity-Relationship model (E-R model) – E-R Diagrams – Introduction to relational databases

Relational Model: The relational Model – The catalog- Types – Keys – Relational Algebra – Domain Relational Calculus – Tuple Relational Calculus - Fundamental operations – Additional Operations- SQL fundamentals – Integrity – Triggers – Security – Advanced SQL features – Embedded SQL – Dynamic SQL – Missing Information – Views – Introduction to Distributed Databases and Client/Server Databases

Text Books

1. Abraham Silberschatz, Henry F. Korth, S. Sudharshan, "Database System Concepts", 5th Edition, Tata McGraw Hill, 2006.
2. C.J.Date, A.Kannan, S.Swamynathan, "An Introduction to Database Systems", 8th Edition, Pearson Education, 2006.

References

1. Ramez Elmasri, Shamkant B. Navathe, "Fundamentals of Database Systems", 4th Edition , Pearson / Addision Wesley, 2007.
2. Raghu Ramakrishnan, "Database Management Systems", 3rd Edition, McGraw Hill, 2003.
3. S.K.Singh, "Database Systems Concepts, Design and Applications", 1st Edition, Pearson Education, 2006.

AV362	Computer Architecture	(3 – 0 – 0) 3 credits

Overview – Organization and Architecture – Structure and function; Computer evolution and performance – History, designing for performance, Evolution of a specific architecture, Performance assessment; Computer functions and interconnections – Computer Components, Functions, Interconnection structures, Bus interconnection; Cache Memory – Overview, Basic principles, Elements of design; Internal Memory; External memory; Input/output; Computer Arithmetic – Arithmetic and Logic Unit, Integer Representation and Arithmetic, Floating-Point Representation and Arithmetic; Instruction Sets – Characteristics and Functions – Machine Instructions, Addressing Modes and Formats, (Either ARM or MIPS); Processor Structure and Function – Processor Organization, Register Organization, Instruction Cycle, Instruction Pipelining (Either ARM or MIPS); Basics of RISC Processors.

Text Books

1. William Stallings, "Computer Organization and Architecture, Designing and performance" – 8th edition – Pearson publications, 2010.

References

1. David A. Patterson, John L. Hennessy, Computer Organization and Design, Fifth Edition: The Hardware/Software Interface, Fourth Edition, The Morgan Kaufmann Series in Computer Architecture and Design, 2011
2. John L. Hennessy, David A. Patterson, Computer Architecture, Fifth Edition: A Quantitative Approach, Fifth Edition, The Morgan Kaufmann Series in Computer Architecture and Design, 2011

Elective 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, 2nd 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.

Master of Science
in
Astronomy & Astrophysics

Semester – VII

ESA411 Astronomical Techniques (3 – 0 – 0) 3 credits

Telescopes and Detectors – optical, infrared, radio, x-rays, gamma-rays, neutrinos and cosmic rays; Gravitational radiation; Detection of dark matter and Dark Energy Astronomy from Space; Imaging – focal plane imagers, PSF and deconvolution, interferometry Photometry, Spectroscopy, Polarimetry, Astrometry; Solar telescopes; Surveys, Astronomical databases, Virtual Observatory.

Text Books/References

1. C.R. Kitchin, Astrophysical Techniques, CRC press.
2. Longair, High Energy Astrophysics vol 1, Cambridge University Press.

ESA412 Radiation Processes in Astrophysics (3 – 0 – 0) 3 credits

Concepts of Radiative Transfer – special relativity – Maxwell's equations – Wave equation – retarded potentials – radiation field – Poynting vector – radiation from accelerated charge – bremsstrahlung – Thomson and Compton scattering – synchrotron radiation – thermal and non-thermal distribution of radiating particles – non-thermal synchrotron radiation – self-absorption – synchrotron and Compton cooling – Inverse Compton catastrophe and brightness temperature limit – propagation effects: dispersion, faraday rotation, depolarization – Atomic and molecular spectra – fine structure and hyperfine transition.

Text Books/References

1. G.B. Rybicki and A.P. Lightman, Radiative Processes in Astrophysics, Wiley.
2. F.H. Shu, The Physics of Astrophysics vol I: Radiative Processes, University Science Books.
3. W.H. Tucker, Radiation Processes in Astrophysics.

ESA413 Planetary Sciences (3 – 0 – 0) 3 credits

Overview of Solar system - Dynamics: Two-body problem, Three-Body Problem (Lagrangian points) - Resonances - Tidal forces - Solar energy balance and transport: Radiative Equilibrium - Planetary Atmospheres: Structure, Composition, Atmospheric Escape - Planetary surfaces: Surface morphology - Impact cratering - Minor Bodies: Meteories, Asteroids, Comets, Minor planets, Trans-Neptunian Objects, Centaurs - Planetary rings - Planet formation: Evolution of protoplanetary disks, Growth of solid bodies, Formation of Terrestrial and Giant planets - Planetary Migration: - Extrasolar Planets: Detection techniques - Estimating planetary masses, sizes, orbital parameters - Habitable zones: factors influencing habitable zone - continuously habitable zone - Missions to study Planets and Extrasolar planets: Overview and Results.

Text Books/References

1. Fundamental Planetary Science: Jack Lissauer & Imke de Pater (Latest Edition) - Cambridge University Press
2. The Solar System: Therese Encrenaz and Jean-Pierre Bibring (Latest Edition) - Astronomy and Astrophysics Library, Springer
3. The Origin and Evolution of the Solar System: Michael M. Woolfson - IoP CRC Press
4. Moons and Planets, W.K. Houtmann, Wadsworth Publishing Company 4th Ed.
5. Exoplanets - Edited by Sara Seager - University of Arizona Press 2011

ESA414	Computational Astrophysics	(2 – 0 – 6)	4 credits

Overview of numerical computation – Simple problems: data sorting, root finding etc. - Numerical solutions of algebraic equations – Numerical integration, interpolation/extrapolation – Numerical differentiation – Ordinary differential equations – Partial differential equations – Statistics, Least-squares fitting – Data crunching, dealing large data set – Fourier transform – Advanced Applications in Astrophysics: N-Body Methods, Hydrodynamics – Monte Carlo Methods.

Text Books/References

1. Numerical Recipes in C, The Art of Scientific Computing, W.H. Press et al.
2. Numerical Methods in astrophysics: An Introduction, Bodenheimer et al., Taylor & Francis, 2007
3. Astrophysics with a PC: An Introduction to Computational Astrophysics, P. Hellings, Willmann-Bell, 1994
4. Data Reduction and Error Analysis for Physical Sciences, P. R. Bevington & K.K. Robinson, McGraw-Hill, 2003

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

ESA431	Data Analysis Astronomy Lab	(0 – 0 – 3)	1 credit

Tutorials on Fitting techniques (linear and non-linear, fits to data with experimental errors, evaluating goodness of fit, etc) and error analysis, Handling of data and getting familiar with data analysis packages like IRAF, AIPS and CASA. This includes an introduction, beginners tutorials and exercises in these softwares as well as and X-ray data analysis.

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

Semester VIII

ESA421	Structure and Evolution of Stars	(3 – 0 – 0)	3 credits

Mechanical, Thermal and Nuclear time scales – Hydrostatic equilibrium (Newtonian and Relativistic) – Polytropic Equation of State – Lane Emden Equation – Degenerte matter Equation of State – White Dwafs and Chandrasekhar limit – Virial Theorem - Radiative Equilibrium – Schwarzschild convection criterion – nuclear energy generation – stages of nuclear burning – full set of stellar structure equations – example solutions – HR diagram and the main sequence – Schonberg-Chandrasekhar limit – post- main sequence evolution – Hayashi tracks – Horizontal branch – giant and asymptotic giant branches – planetary nebula formation – supernovae – compact objects.

Text Books/References

1. R. Kippenhahn and A. Weigert, Stellar Structure and Evolution, Springer.
2. A. Weiss et al, Cox and Giuli's Principles of Stellar Evolution, Cambridge Scientific Publishers.
3. Dina Prialnik, An introduction to the theory of stellar structure and evolution, Cambridge University Press.
4. S. Chandrasekhar, An introduction to the Study of Stellar Structure, Dover.

ESA422	Galaxies (Structure, Dynamics and Evolution)	(3 – 0 – 0)	3 credits

Classification of galaxies – contents and dimensions – collisionless stellar dynamics – relaxation time, dynamical friction, violent relaxation – galactic potential and orbits – spiral density wave and Lindblad resonance – rotation curves – Tully-Fisher relation – Central Black Holes and fundamental plane relationship – Mass and Luminosity function – Press Schechter formalism – Star formation history and chemical evolution – active galaxies and activity duty cycle – galaxies at high redshift - clusters and groups – evidence of dark matter

Text Books/References

1. L.S. Sparke and J.S. Gallagher, Galaxies in the Universe, Cambridge University Press.
2. J. Binney and S. Tremaine, Galactic Dynamics, Princeton University Press.
3. J. Binney and M. Merrifield, Galactic Astronomy, Princeton University Press.
4. A.K. Kembhavi and J.V. Narlikar, Quasars and Active Galactic Nuclei: An Introduction, Cambridge University Press.

ESA423	Cosmology	(3 – 0 – 0)	3 credits

Principles of Relativity: Overview of Special Relativity – spacetime interval and Lorentz metric – four vectors – Introduction to general relativity (GR) – equivalence principle – notions of curvature – gravitation as a manifestation of the curvature of spacetime – gravitational redshift and clock corrections – orbits in strong gravity, light bending and gravitational lensing – concept of horizon and ergosphere, hydrostatic equilibrium in GR – gravitational radiation.

Cosmological Models: Universe at large scales – Homogeneity and isotropy – distance ladder – Newtonian cosmology – expansion and redshift – Cosmological Principle – Hubble's law – Robertson-Walker metric – Observable quantities – luminosity and angular diameter distances – Horizon distance – Dynamics of Friedman- Robertson-Walker models: Friedmann equations for sources with p=wu and w =−1, 0, 1/3, discussion of closed, open and flat Universes.

Physical Cosmology and Early Universe: Thermal History of the Universe – distribution functions in the early Universe – relativistic and nonrelativistic limits – Decoupling of neutrinos and the relic neutrino background –

Nucleosynthesis – Decoupling of matter and radiation – Cosmic microwave background radiation (CMB) – Anisotropies in CMB - Inflation – Origin and growth of Density Perturbations – Formation of galaxies and large scale structures – Accelerating universe and type-Ia supernovae – The Intergalactic medium and reionization.

Text Books/References

1. Cosmological Physics, Cambridge University Press, J . A. Peacock
2. An Introduction to Relativity, J. V. Narlikar, Cambridge University Press, 2010 (For the lectures on General Relativity and Cosmology).
3. Theoretical Astrophysics, Volume III: Galaxies and Cosmology, T. Padmanabhan,Cambridge University Press, 2002 (for lectures on Cosmology)
4. Classical Theory of Fields, Vol. 2, L. D. Landau and E. M. Lifshitz, Oxford : Pergamon Press, 1994 (For more material on General Relativity).
5. Introduction to Cosmology, J. V. Narlikar, Cambridge University Press, 1993 (For the lectures on Cosmology).
6. First course in general relativity, B. F. Schutz, Cambridge university press, 1985 (For material on General Relativity).
7. Structure Formation in the Universe. T. Padmanabhan, Cambridge University Press, 1995 (for material on Cosmology and Structure formation).

ESA4xx	PG Elective II	(3 – 0 – 0)	3 credits

ESA441	Observational Astronomy Lab	(0 – 0 – 6)	2 credits

CCD characterisation, Orbit maker and Virtual Observatory, Night sky observations (Polar alignment of an astronomical telescope, Estimating atmospheric extinction in different colours (filters), measuring period of binary, imaging star clusters with various filters and plotting on H-R diagram, Distance determination to Cepheid variables based on their light curves, Classification of stars based on their spectra and the use of spectral classification in deriving distances to stars, etc).

ESA451	Seminar I	(0 – 0 – 0)	2 credits

ESA452	Comprehensive Viva-Voce II	(0 – 0 – 0)	2 credits

Semester IX

ESA551	Seminar II	(0 – 0 – 0) 2 credits

ESA552	Thesis Phase I	(0 – 0 – 0) 16 credits

Semester X

ESA553	Thesis Phase II	(0 – 0 – 0) 17 credits

PG Elective Courses

ESA461 Gas Dynamics (3 – 0 – 0) 3 credits

Conservation laws – Euler's Equations – Common Equations of State – Hydrostatic Equiibrium – Isothermal sphere – Virial Theorem – linear perturbation theory – acoustic waves – Jeans' instability – Rayleigh Taylor instability – de Laval nozzle – Parker wind solution – Bondi accretion – Shock waves – Sedov solution – elements of plasma physics – Debye screening – orbit theory – elements of MHD – flux freezing – Alfven waves – Langmuir oscillations – dispersion relation of electromagnetic waves propagating in plasmas – plasma instabilities – transport phenomena.

Text Books/References

1. F.H. Shu, The Physics of Astrophysics vol II: Gas Dynamics, University Science Books.
2. M.J. Thompson, An Introduction to Astrophysical Fluid Dynamics, Imperial College Press.
3. Arnab Rai Choudhuri, The Physics of Fluids and Plasmas, Cambridge University Press.
4. Francis F Chen , Introduction to Plasma Physics and Controlled Fusion, Springer.

ESA462 Physics of Interstellar and Intergalactic Medium (3 – 0 – 0) 3 credits

Occurrence and state of cosmic diffuse matter – ionized, atomic, molecular gas and dust – heating and cooling, equilibrium phases – probes of diffuse matter (line and continuum radiations at various wavelengths) – Thermal and ionization equilibrium of HII regions – UV shielding in molecular gas – extinction/reddening/polarization due to dust – dust heating and IR emission – star forming regions - cosmic rays and non-thermal synchrotron emission – recombination and re-ionization of IGM – Lyman alpha forest, Mg absorption systems – Gunn Peterson effect – Heating of intracluster gas – Sunyaev- Zeldovich effect – excess entropy problem and possible resolution.

Text Books/References

1. M.A. Dopita and R.S. Sutherland, Diffuse Matter in the Universe, Springer.
2. D.E. Osterbrock and G.E. Ferland, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei, University Science Books.
3. L. Spitzer, Physical Processes in the Interstellar Medium, Wiley.
4. D. Mihalas and J. Binney, Galactic Astronomy, Princeton University Press .
5. J.E. Dyson and D.A. Williams, The Physics of the Interstellar Medium, IOP publishing.

ESA463 High Energy Astrophysics (3 – 0 – 0) 3 credits

Radiation-matter interaction – Sources of high energy (UV-gamma rays) radiation in the universe – Detectors for high energy particles, X-rays, gamma rays and neutrinos – Space astronomy – Elements of General Relativity – compact stars – magnetospheric processes around neutron stars (pulsars and magnetars) – interacting binaries – Roche potential and accretion – Shkura-Sunyaev thin disk model – accretion phenomenology around compact objects – stellar mass black holes vs supermassive black holes – AGN phenomenology and unified scheme – Jet production and superluminal motion – Supernova remnants and shock acceleration of relativistic particles – Gamma Ray Bursts.

Text Books/References

1. M. Longair, High Energy Astrophysics, vol. 1 and 2, Cambridge University Press
2. F. Melia, High Energy Astrophysics, Princeton University Press

3. Ya B. Zeldovich and I.D. Novikov, Relativistic Astrophysics, vol. I, Stars and Relativity

ESA464 Estimation and Stochastic Processes (3 – 0 – 0) 3 credits

Elements of probability theory – random variables – Gaussian distribution – stochastic processes – characterizations and properties – Gauss-Markov processes – Brownian motion process – Gauss-Markov models – Optimal estimation for discrete-time systems – fundamental theorem of estimation – optimal prediction. Optimal filtering – Weiner approach – continuous time Kalman Filter – properties and implementation – steady-state Kalman Filter – discrete-time Kalman Filter – implementation – sub-optimal steady-state Kalman Filter – Extended Kalman Filter – practical applications. Optimal smoothing – Optimal fixed-interval smoothing – optimal fixed-point smoothing – optimal fixed-lag smoothing – stability – performance evaluation.

Text Books/References

ESA465 Formation of Stars and Planets (3 – 0 – 0) 3 credits

The interstellar medium and its phases – dust – molecular clouds – virial theorem analysis. Star clusters – OB associations – T and R associations – initial mass function. Heating and cooling of clouds – cloud thermal structure – build up of molecules – molecular transitions of H_2, CO. Cloud equilibrium and stability – Jeans mass – isothermal spheres – basic magnetohydrodynamics – magnetic support – ambipolar diffusion – inside-out collapse – rotational effects. Collapse of dense cores – accretion – Deuterium burning – protostellar disks – fragmentation – formation of binaries and stellar groups – jets and molecular outflows – masers. Formation of massive stars – monolithic collapse – competitive accretion – stellar mergers. Effects of massive stars – hot cores – ultracompact HII regions – photoevaporation – induced star formation. Quasi-static contraction – nuclear reactions and stellar birth line – T-Tauri stars – Herbig Ae/Be stars – debris disks – planet formation in disks.

Text Books/References

1. The Formation of Stars by S. W. Stahler and F. Palla, 2004 – Wiley - VCH
2. The Origin of Stars and Planetary Systems, 1999, eds. C.J. Lada and N.D. Kylafis
3. Protostars and Planets V, 2007, eds. B. Reipurth, D. Jewitt, and K Kell
4. Accretion Processes in Star Formation, 1998, L. Hartmann
5. Astrophysics of Planet Formation, 2010, P. Armitage

ESA466 Advanced Astronomical Imaging (3 – 0 – 0) 3 credits

Imaging and detector basics – resolution, sensitivity, noise, dynamic range, efficiency, linearity – image formation at focal plane – Fourier transform – Deconvolution and Image reconstruction – Photography CCD -- Large optical/IR telescopes and their designs – thin lens – segmented mirrors – Active optics – Designs of few upcoming large telescopes (eg. EVLT, TMT) – Techniques to overcome atmopsheric turbulence – Fried parameter – Isophase patches and speckles – Adaptive optics – Lucky imaging – Speckle imaging – Interferometry – Basic principles – Michelson stellar interferometer – Aperture synthesis – VLBI – New and Upcoming missions – eVLA, ALMA, SKA – Non focussing methods – Tubular and modulation collimators, Coded masks, Fresnel zone-plates – Astrotomographic techniques – Lunar occultation, eclipse mapping, doppler tomography, echo mapping.

Text Books/References

1. Electronic Imaging in Astronomy: Detectors and Instrumentation - Ian S. McLean, Springer, 2008
2. Adaptive Optics for Astronomical Telescopes - John W. Hardy, Oxford Series in Optical & Imaging Sciences, 1998

3. Astrotomography: Indirect Imaging Methods in Observational Astronomy, Editors: H.M.J. Boffin, D. Steeghs, J. Cuypers, Springer Lecture series, 2001
4. Interferometry and Synthesis in Radio Astronomy - Thompson, Moran & Swenson, Wiley, 2001
5. Lucky Exposures:: Diffraction Limited Astronomical Imaging through the Atmosphere - Robert Tubbs, VDM Verlag Dr. Müller, 2010
6. Astronomical Image and Data Analysis - J.-L. Starck, F. Murtagh, Astronomy and Astrophysics Library, 2006

ESA467 Radiation Hydrodynamics (3 – 0 – 0) 3 credits

Introduction: How radiation affects the flow of matter – Cooling, Heating, Momentum transfer, Matter density variation due to annihilation/pair-production. Review of gas dynamics: Ideal fluids, Transport terms – Viscosity & heat conduction, Sound waves, Shocks – Rankine-Hugoniot relations. Review of radiation physics: Intensity, Flux, Energy density, Stress tensor, Transport equations, Diffusion approximation, Coupling terms in Euler's equations. Steady state transfer: Radiation-matter interaction: Einstein's coefficients, Scattering, Ionization/recombination, Opacity calculations, Spectral line transport. Polarized light in the equation of transfer: Hydrodynamics with radiation: non-adiabatic waves, atmospheric oscillations with radiation pressure, Relativistic hydrodynamics in the presence of a radiation field. Numerical techniques for radiation transport. Examples: Ionization fronts, Comptonization, Radiating shock waves, Radiatively driven stellar winds.

Text Books/References

1. Foundations of Radiation Hydrodynamics, Dimitri Mihalas, Dover Pbl.
2. Radiation Hydrodynamics, John I Castor, Cambridge Press.
3. The equations of Radiation Hydrodynamics, Gerald C Pomraning, Dover pblcns

ESA468 Accretion Physics (3 – 0 – 0) 3 credits

Introduction: Accretion as a source of energy – observational consequences. Accretion in binary system: Introduction – Interacting binary system – Roche lobe overflow – Disk formation – Viscous torque – The α disk viscosity – Low and high-mass X-ray binaries. Accretion disk (thin accretion disk) Theory: Basic concepts – Structure of thin disk – The emitted spectrum of steady α-disk – Time dependence and stability – the thermal disk instability model (dwarf novae) – wind accretion – Disk around young stars – confrontation with observations. Accretion on to compact object: Boundary layers – Accretion on to magnetized neutron star and white dwarf – accretion column – accretion on to black hole. Accretion disks in AGN: AGN models – Radio, millimeter and infrared emission – optical, UV and X-ray emission – broad and narrow line region – Extended and compact radio sources – The Blandford-Znajek model. Thick discs: The limiting luminosity – accretion tori – self-gravitating disks and their stability – astrophysical implication. Accretion flows: The governing equations – A unified description of steady flow – advection-dominated flows – general transonic accretion solution in presence of heating and cooling.

Text Books/References

1. Accretion Power in Astrophysics by Juhan Frank, Andrew King, Derek Raine (Cambridge University Press)
2. Accretion Processes in Star Formation by Lee Hartmann (Cambridge Astrophysics)
3. Theory of Transonic Astrophysical Flow by Sandip K. Chakrabarti (World Scientific)

ESA469 High Redshift Universe (3 – 0 – 0) 3 credits

Basic cosmology – Expansion of the universe – scale factor – cosmological redshift – descriptive overview of inflation, unification of forces and fundamental particles. Primordial nucleosynthesis – elemental abundances: predictions and observations. Cosmic Microwave Background – detection, power spectrum, origin of CMB, anisotropies in the CMB and their origin – overview of COBE and WMAP probes – mission and instrumentation. Reionization of the universe – quasar absorption line observations – Gunn-Peterson trough – sources of reionization – first stars, AGNs, Lyman Break Galaxies – the reionization process. Detection of galaxies at high redshift – radio, sub-mm, IR surveys – photometric redshifts – drop-outs – Ly-alpha emitters. Comparison of high-z galaxy properties with the present universe – morphology, stellar content, sizes, luminosity function, baryon budget etc.

Clusters and groups of galaxies, morphology-density relationship, Butcher-Oemler effect. High Redshift Supernova – observations used to discover and measure SNe Ia (supernova rates, light curves, spectroscopic data) – standard candle (heterogeneity in SNe brightness and light curve shapes) – SNe Type Ia data sets (SDSS, SNLS, HST etc) – constrains on cosmological parameters mass density, dark energy density.

Text Books/References

1. The Early Universe (Frontiers in Physics) : Edward Kolb, Michael Turner, Wesview Press, 1994.
2. The Physics of the Cosmic Microwave Background : Pavel D. Naselsky, Dmitry I. Novikov and Igor D. Noyikov, Cambridge Astrophysics Series - 41.
3. Galaxies in the Universe : Linda Sparke, John Gallagher, Cambridge University Park
4. High Redshift Galaxies : Immo Appenzeller, Astronomy & Astrophysics LIbrary, Springer

ESA470 Polarization in Astronomy (3 – 0 – 0) 3 credits

Unpolarised light, Linear, Circular, Elliptical polarised light, Partially and fully polarised light, Stokes parameters, Dichroism, Birefringence, Poincare sphere – Mueller and Jones representations with applications – Complex plane of polarisation states.

Generation of polarised light in astronomy – polarisation by reflection, scattering geometry, magnetic fields - dependence on refractive index – synchrotron emission – Faraday rotation – Dust in ISM. Instrumental polarisation errors and their calibration.

Optical/infrared polarimetry – Polaroids, Wave plates, Wollaston prism, Modulators – photoelastic modulators, liquid crystals – compound zero order plates, achromatic retarders, fresnel rhombs, modulators with CCDs, Two beam analysers, Achromatic systems, imaging and spectropolarimetry.

Radio polarimetry – Orthogonal dipoles as feeds, Native linear and circular feeds, correlation, synthesis array and VLBI. X-ray polarimetry – Bragg Polarimeters, Thompson/Compton Polarimeters, Gas Pixel Detector (GPD) solution, Time Projection Chamber (TPC) polarimeter solution, X-ray polarimetry – future missions .

Text Books/References

1. Astronomical Polarimetry - J. Tinbergen, Cambridege University Press
2. Polarized light by Dennis Goldstein (3rd Edition) Marcel Dekker Inc (ISBN: 0-8247-4053-X)
3. X-ray Polarimetry--Edited By Ronaldo Bellazzini Enrico Costa Giorgio Matt Gianpiero Tagliaferri Publisher: Cambridge University Press (2010)
4. Introduction to the theory of Coherence and polarisation of light - Emil Wolf

ESA471 High Resolution Spectroscopy (3 – 0 – 0) 3 credits

Atomic structure: review of Schrodinger equation – overview of single and multiple electron systems – perturbations and level splittings – parity – spin orbit coupling – Zeeman effect – hyperfine structure – Boltzmann population of energy levels in thermal equilibrium – Saha equation. Radiative transitions: semi-classical theory – dipole approximation – Einstein coefficients and oscillator strengths – selection rules and transition rates. Molecular Structure: Born-Oppenheimer approximation – electronic binding of nuclei – H_2 molecule – energy levels and selection rules for pure rotation spectra, rotation-vibration spectra and electronic-rotational-vibrational spectra. Observational techniques for spectroscopy: linear and angular dispersion – dispersion elements: prism, diffraction gratings and echelles (chromatic vs slit limited resolution, free spectral range, pre-dispersers and cross-dispersers) – Fabry-Perot etalon – Fourier Transform spectrometers – digital spectrometers – multi-object spectrographs (e.g. integral field spectroscopy). Applications of high resolution spectroscopy: Elemental abundances in stars – absorption line studies of cold ISM (radio) and IGM (Lyman alpha forest) – radial velocity searches for extra-solar planets – Zeeman effect – infall and outflow signatures in star forming cores.

Text Books/References

1. Radiative Processes in Astrophysics by Rybicki & Lightman
2. Spectra of Atoms and Molecules by Bernath
3. Astrophysical Techniques by Kitchin

ESA472	Time Domain Astronomy	(3 – 0 – 0)	3 credits

Scientific background : Variable stars, binary stars and their evolution, supernovae, pulsars and associated phenomena (even include testing theories of gravity using pulsars), accretion and associated phenomena (like x-ray bursts), gamma-ray bursts, rotating radio transients (RRATS), jets & outflows (micro-quasars etc), AGNs-blazars-QSOs.

A survey of missions and their ways of operation [can go to technical levels, to the operations of these instruments]: Optical/IR surveys: Pan-STARRS (Panoramic Survey Telescope and Rapid Response System), PTF (Palomar Transient Factory), Transients search & robotic telescopes, High energy surveying missions: Swift, Fermi, AGILE, Radio surveys: LOFAR (Low-Frequency Array for Radio astronomy), SKA (Square Kilometre Array), Stellar variability studies: Kepler space craft, Future missions:- Gravitational waves & time domain astronomy (simultaneous GW and EM observations), LSST (Large Synoptic Survey Telescope**),** Data handling and analysis, Multi wave-band modeling [isis etc], Time series analysis.

Text Books/References

ESA473	Exoplanets and Astrobiology	(3 – 0 – 0)	3 credits

Properties of known exoplanets – exoplanet surveys – detection methods – formation, interior and evolution of planets – brown dwarf exoplanets connection – close orbiting exoplanets – multiple planet systems – planets in binary systems – moons of exoplanets.

Origin of life – prebiotic molecules and development of life forms – habitable zone – Mars and life – Icy bodies (Europa and others) – Titan's atmosphere – detection of exoplanets – search for extraterrestrial life.

Text Books/References

1. Exoplanets: Detection, Formation, Properties and Habitability by John W Mason, Springer
2. Extrasolar Planets by Cassen, Patrick, Guillot, Tristan, Quirrenbach, A. Queloz, D.; Udry, S.; Mayor, M.; Benz, W. (Eds.), SAAS Fee Advance Course 31, Springer
3. An introduction to Astrobiology by I. Gilmour and M.A. Sephton, Cambridge University Press.

ESA474	Physics of the Sun	(3 – 0 – 0)	3 credits

Characteristics of the Sun – internal structure – solar observations – solar atmosphere – oscillations – Convection – rotation – magnetism – chromosphere – corona – solar wind – quiet Sun – Active Sun – Helioseismology.

Text Books/References

1. The Sun – An Introduction by Michael Stix, Second Edition, A & A Library, Springer

2. Fundamentals of Solar Astronomy by Arvind Bhatnagar and William Livingston, latest edition, World Scientific
3. Solar Astrophysics by Peter Foukal, Third Edition, Wiley-VCH

Master of Technology
in
Earth System Science

Course	Dual Degree
Semester	VII
Subject Code	ESE 411
Subject Title	Dynamics of Atmosphere

Syllabus:

Concept of fluid, Continum model, Lagrange and Eulerian description of fluid flow, continuity, momentum and energy equations, boundary layer theory, turbulent flow, Inertial

and Non Inertial frames; Fundamental Forces - Pressure Gradient Forces, Gravitational Force, Friction or Viscous Force, Apparent forces -Centrifugal Force, Coriolis force, Rossby number, Effective Gravity; Hydrostatic balance, Momentum Equations-Cartesian Coordinate System, Spherical – Polar coordinate system. Scale analysis of momentum equations. Balanced motion - Geotropic Wind, Gradient Wind, Inertial flow, Cyclostropic flow, Thermal wind, Continuity equation – Horizontal divergence, Vertical motion. Isobaric coordinate System -Transformation of momentum & continuity equations. Circulation & Vorticity – Kelvins circulation theorem, Bjerknes circulation theorem. Application to Land & Sea breeze.

Vorticity equation. Potential vorticity - Application to Lee of the mountain trough, divergence equation, linear and non-linear balance equations, scale analysis of vorticity and divergence equations for planetary and synoptic scale motions;

Atmospheric waves –sound wave, gravity wave, Rossby wave, Quasi-geostrophic analysis- quasi-geostrophic omega equation,the general circulation- available potential energy,-barotropic instability, baroclinic instability, tropical dynamics

Course	Dual Degree
Semester	VII
Subject Code	ESE 412
Subject Title	Physical and Dynamical Oceanography

Syllabus:

Unit I:

Physical properties of Sea water, density of sea water, density parameters, specific volume anomaly, Temperature, Salinity, Cholorinity and their determination, distribution of temperature, salinity and density in space and time, The oceanic Mixed Layer and Thermocline, Sea level variation, acoustical and optical properties of sea water, Formation and classification of water masses, T-S diagram and Water masses of the world ocean.

Waves and Tides: General aspects of ocean waves, Waves and Tides; wave characteristics, wave generation and propagation, Sea and Swell, Deep and Shallow water waves, storm surges and tsunamis; Tides and tide generating forces; their causes, variation, and types, Tidal currents.

Unit II:

Equations of Motion: Dominant Forces for Ocean Dynamics, Coordinate Systems, Types of Flow in the Ocean, Conservation of Mass and Salt, The Total Derivative, Momentum Equation, Conservation of Mass: Continuity Equation, Solutions to the Equations of Motion. Stability in the Ocean, Mixing in the Ocean.

Geostrophic Currents: Hydrostatic Equation, Geostrophic Approximation, Geostrophic Currents, Barotropic and Baroclinic Flow. Response of the Upper Ocean to Winds: Ocean Circulation; Inertial Motion, Ekman Layer and Ekman currents, Ekman Spiral, Vertical circulation, Ekman Transports, Application of Ekman Theory; upwelling and sinking, Thermohaline circulation, Currents in the Ocean, Westward intensification of currents, warm and cold currents of the major world ocean. Seasonal currents in the North Indian Ocean, Deep circulation in the ocean: Importance of the deep circulation, role of the oceans in climate and abrupt climate change, Stommel-Arons' theory of the deep circulation, Antartic Circumpolar Current. Equatorial Processes: Surface and subsurface currents, El Niño/La Niña: The variability of the equatorial currents, El Niño influence global weather.

Course	Dual Degree
Semester	VII
Subject Code	ESE 413
Subject Title	Earth Resources and Tectonic Systems

Syllabus:

Internal Structure of Earth:

Introduction to Earth and formation theories. Seismicity and earth's interior. Compositional and Rheological divisions of Earth; crust, mantle and core; discontinuities. Mineralogy and Earth Resources. Minerals, ores, petroleum, coal and natural gas- their origin, structure and composition, accumulation/migration, source/reservoir rocks, distribution in space and time. General physical, chemical and optical properties of common rock forming minerals.

Igneous, Metamorphic and Sedimentary Petrology:

Rock cycles and processes involved; Formation, classification and distribution of volcanoes; partial melting and formation of primary magmas; evolution of magmas; igneous processes.

Sedimentary rocks and environment of formation, sedimentary basins Metamorphic processes, factors and types of metamorphism, grades and facies of metamorphism. Properties and formation mechanisms of common igneous, metamorphic and sedimentary processes. Geologic work of natural agents- atmosphere, wind, water and glaciers

Tectonic Systems:

Concept of continental drift, sea-floor spreading and plate tectonics; tectonics. Nature of plate boundaries: convergent, divergent and transform type. Precambrian and Phanerozoic plate tectonics. Evolution of the Himalayas, Indian Ocean and Andaman's.

Course	Dual Degree
Semester	VII
Subject Code	ESE 414
Subject Title	Radiation Processes in Atmosphere

Syllabus:

The spectrum of electromagnetic radiation; Solid angle, Fundamental of radiometric quantities, Concepts of scattering, absorption and polarization of radiation, Quantitative description of radiation; Blackbody Radiation: The Plank Function, Wiens displacement Law, The Stefan-Boltzmann Law; Kirchoff's Law, Radiative equilibrium.

Absorption line profiles: Line formation and line shape, Absorption and emission by gas molecules, Physics of scattering and absorption by particles, Rayleigh Scattering, Raman Scattering, Lorentz-Mie theory of light scattering, Geometric Optics.

Radiative transfer in planetary atmosphere, Equation of radiative transfer, Radiative transfer in a plane parallel atmosphere, Beer-Bouguer Law, Reflection and absorption by a layer of the atmosphere, Absorption and emission of infrared radiation in cloud-free atmosphere, Vertical profiles of radiative heating rate; Earth's radiation budget, the Role of radiation in climate.

Application of radiative transfer to remote sensing of atmospheric properties: Retrieval of meteorological variables, gases, particulate information and surface properties.

Course	Dual Degree
Semester	VII
Subject Code	ESE 415
Subject Title	Atmospheric Thermodynamics and Cloud Physics

Syllabus:

Basic concepts, composition of the atmosphere, equation of state, hydrostatic equilibrium, first law of thermodynamics, application of first law, entropy, second law, heat capacity, dry adiabatic processes, transfer processes, moist thermodynamic processes in atmosphere, static stability, cloud characteristics and processes, Global energy and entropy balances, thermodynamic feedback in the climate system, thermodynamic diagrams.

Cloud Physics: Types of clouds, Cloud microphysical processes, growth of cloud droplets, condensation, collision and coalescence, Bergeron-Findeisen theory, rain formation, cold and warm clouds, artificial rainmaking. Effects of Aerosols on Clouds: Cloud Condensation Nuclei, Cloud Droplet Spectra, and Precipitation (Heterogeneous Nucleation of water vapour condensation, Cloud Condensation Nuclei, Development of Cloud Droplet Spectra, Effects of Clouds on Aerosols: Nucleation of Aerosol in and near Clouds.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 461
Subject Title	Planetary Atmospheres

Syllabus:

Introduction to Planets and Planetary Systems- Orbital motion – Gravitational field that shape the Earth – Internal structure of planet and its satellite, Equation of state, Density profiles, Mass-Radius relationship, The origin and evolution solar system, planetary atmospheres, Elemental abundance, outgassing processes, capture processes, Erosion and escape processes, surface processes – condensation, Adsorption, dissolution, chemical weathering, Atmospheric feedbacks – Observed atmospheric changes in Earth and other planets.

Spectroscopy and composition of planetary atmospheres, Processes causing compositional variations, Vertical temperature structure of Venus, Mars Titan, Jupiter, Uranus and Neptune. Water on Mars, Venus and Jupiter, Thermal tides, Lapse rate, Radiative transfer in planetary atmospheres, Clouds in Planetary atmospheres, Structure of clouds in Venus and Mars, Cloud Microphysics, Dust Dynamics and Storms, The general circulation regimes, Dynamics of Earth, Venus, Mars and other Jovian planets hydrodynamic instabilities, modelling of planetary atmosphere, Climate of Venus, Mars, Mechanism of climate change in Planetary atmospheres, Atmospheres of Exoplanets.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 462
Subject Title	Numerical Weather Prediction

Syllabus:

Introduction: Numerical Weather Prediction as an Initial Value Problem, Filtering Problem, Finite Difference techniques for various partial differential equations (parabolic, hyperbolic and elliptic), Time integration schemes, Explicit, Implicit, and semi-implicit Schemes.

Consistency and stability [CFL condition], Von Newmann stability analysis for various finite difference schemes, Staggered grid, Nonlinear instability,Arakawa Jacobians, Semi lagrangian methods, Spectral Technique, Galerkin methods, Introduction to Hierarchy of numerical models: Barotropic models, Equivalent barotropic model, Two level baroclinic model, Shallow water model, Primitive equation models, Brief overview of sub-grid scale processes (convection, boundary layer, radiation, land surface), Objective analysis, Initialization schemes, Data assimilation, Variational schemes, Kalman Filter schemes , High resolution regional modelling- Nested grids, Boundary conditions , Ensemble forecasting

Course	Dual Degree
Semester	VIII
Subject Code	ESE 463
Subject Title	Planetary Geosciences

Syllabus:

Remote Sensing techniques applicable to planetary geology; applications derived from interaction of electromagnetic radiation (X-ray, gamma-ray, visible, near-IR, mid-IR, radar) with geologic materials. Remote sensing applications formineralogy, petrology and geochemical analyses for terrestrial and extraterrestrial environments.

SolarSystem: major concepts, planets, satellites, asteroids, meteorites and comets; formation and internal differentiation of the planets; general features of Terrestrial and Jovian planets.

Planetary atmospheres; exo- and endogenic processes associated with origin and internal evolution of planets – planetary volcanism, craters, impact cratering processes, elemental composition; mineralogy and petrology; thermal, seismic and magnetic properties, and chronological techniques.

Earth as a reference material; geology and geophysics of terrestrial planets: mars, venus and mercury; comparative planetology of Jupiter, Uranus and Saturn and their satellites; physical properties, composition, mineralogy and petrology of the air less rocky bodies: the Moon and its Terrestrial Analogues, Io, Phobos and Deimos, minor bodies such as asteroids, comets, meteor, meteoroid and meteorites.

Past, present and future planetary exploration missions.

Analyses and Interpretation of data gathered through various missions: identification of surface and morphological features, mineralogy and petrology.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 464
Subject Title	Aerosol-Cloud-Climate Interaction

Syllabus:

Tropospheric Aerosols: Aerosols, Historical understanding of tropospheric aerosols, Contemporary understanding of tropospheric aerosols; Particle Sources and Strengths - widespread surface sources (Biogenic sources, Volcanoes, Ocean and fresh water, Crustal and Cryospheric Aerosols, Biomass burning); Spatial Sources - Gas to particle conversion (Sulfur & Nitrogern - Containing compounds, Organic and Carbonaceous Particles), Cloud as a Source of Aerosols, External Sources; Particle Size Distribution and Chemical Compositions (Polar aerosols, Background aerosols, Maritime aerosols, Remote continental aerosols, Desert dust storm aerosols, Rural aerosols, Urban aerosols); Transport, Geographical Distribution, Residence Time and influence of Clouds, Aerosol Optical Depth; Cloud Optical depth and Effective Particle Radius.

Cloud Physics: Types of clouds, Cloud microphysical processes, growth of cloud droplets, condensation, collision and coalescence, Bergeron-Findeisen theory, rain formation, cold and warm clouds, artificial rainmaking.

Aerosol-Cloud Interaction: Effects of Aerosols on Clouds: Cloud Condensation Nuclei, Cloud Droplet Spectra, and Precipitation (Heterogeneous Nucleation of water vapour condensation, Cloud Condensation Nuclei, Development of Cloud Droplet Spectra, Effect of Aerosol on Development of Precipitation, Stability of CCN population); Aerosol Effects on Cloud Radiative Properties (Effect of Aerosol on Cloud Optical Thickness and Albedo, Effects of Fossil Fuel and Biomass Burning, Ship tracks in Clouds, DMS-Cloud-Climate Hypothesis, Aerosol Effects on Ice in Clouds- Ice Nuclei). Effects of Clouds on Aerosols: Scavenging of Aerosol by Clouds (In-cloud Nucleation Scavenging, Below-Cloud Removal of Aerosol by Precipitation); Chemical Reaction in Clouds and their effects on Aerosol; Acidification of Cloud water and Precipitation; Nucleation of Aerosol in and near Clouds.

Aerosol-Cloud-Climate interaction: direct and indirect radiative forcing; Radiative effects of Clouds on Earth's Climate: Cloud radiative forcing, Radiation budget and Cloud Climatologies, Effects of Clouds on Surface and Atmospheric Energy Budgets.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 465
Subject Title	Air-Sea Interaction

Syllabus:

The significance of Air-Sea Interaction; Atmospheric and Oceanic Interaction at various scales; Concept of Boundary Layer; Atmospheric Heat Budget; Variations of wind, temperature and moisture over the sea surface. Air sea temperature differences; Wind stress and resultant drag coefficient with variation to wind speed; Upper ocean boundary layer. Oceanic heat budget.

Physical interaction between the Ocean and Atmosphere, Radiation - Solar radiation, Longwave radiation; Heat exchange through latent and sensible heat; The Oceanic heat balance; Oceanic forcing by air-sea exchange of moisture and heat - Moisture exchange, Air-Sea Momentum transfer and drag - Charnock's Law, Sea Surface Roughness, Wind-driven circulation of the Ocean – Ocean Gyres, Ekman flow, Coastal upwelling, upwelling and sinking with special reference to the Indian Ocean, The tropical surface circulation, The Indian Ocean monsoonal circulation, Thermohaline circulation.

Large-scale Air-Sea interaction: Ocean-Atmosphere interaction in the tropics, Genesis and characteristics of ENSO; ENSO and air - sea coupling, Global impact of ENSO, ENSO and the Indian Monsoon.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 466
Subject Title	Satellite Meteorology and Oceanography

Syllabus:

History of satellite and radar meteorology; Orbits and navigation, Orbit perturbations, Meteorological satellite orbits, Satellite positioning, tracking, and navigation, Space-time sampling, Launch vehicles and profiles; Elements of radiative transfer - Basic quantities, Blackbody radiation, Radiative transfer equation, Gaseous absorption, Scattering, Solar radiation and surface reflection; Meteorological satellite instrumentation - Operational polar orbiting satellites, Operational geostationary satellites, Other satellite instruments, Satellite data archives; Radar - Radar basics, Conventional weather radar, Radar measurements of rainfall, Comparison with satellite rainfall products, NEXRAD system, Applications to hydrology; Image interpretation; Satellite -Visible infrared and water vapor imagery, Spectral properties, Image enhancement techniques, Geo-location and calibration; Doppler radar Doppler wind measurements, reflectivity, Analysis of Doppler measurements, Atmospheric temperature and water vapor profiles, Winds, Clouds and aerosols, Precipitation; Integrated application topics - Hurricanes, Severe Storms, Agriculture Applications. Introduction to satellite remote sensing of the ocean; Propagation and sensing of EM waves and their interaction and scattering with the ocean's surface; Atmospheric absorption and scattering of microwave; visible and infrared radiation; Celestial mechanics for understanding orbital dynamics and geometric distortions; Brief review of electromagnetic wave theory, antenna patterns and ocean surface processes; Detailed survey of major instruments for measuring oceanographic variables from space; Applications of visible, infrared, and microwave observations using objective, multi-spectral, and characteristic vector analysis; Emphasis on new methodologies, error assessments, sampling considerations and data interpretation.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 467
Subject Title	Boundary Layer Meteorology

Syllabus:

Introduction: definitions and background, variables, wind and flow, turbulent transports; Taylor's hypothesis and observing techniques, boundary layer depth and structure Mathematical and conceptual tools: Turbulence and its spectrum; spectral gap; mean and turbulent parts; basic statistical methods; rules of averaging; turbulent kinetic energy; kinematic flux, eddy flux; stresses. Governing equations for turbulent flow: methodology, basic equations, simplifications and approximations, equations for mean variables in a turbulent flow. Mixed layer theory: mixing and entropy; governing equations, model behavior, surface fluxes and entrainment. Cloud-topped boundary layers: moisture variables; radiative processes, observed structure; governing equations, entrainment. Trade wind boundary layer: mean structure and fluxes; moist convective processes; sub-cloud layer interactions; strato-cumulus to trade cumulus transitions. Deep convection and Marine boundary layer: controls on deep convection; MABL modification by downdrafts; boundary layer recovery; boundary layer modeling and parameterizations.

Course	Dual Degree
Semester	VIII
Subject Code	ESE 468
Subject Title	Polar Science

Syllabus:

Overview of Polar Geography and Climate; History of Indian Antarctic programme; Physical characteristics; weather and climate, ice coring in Antarctica for Paleo-environment studies, logistics of Antarctic Science, opportunities, Antarctic governance and protection of Antarctic environment, International linkages.

Ice characteristics and physical oceanography of polar seas; Sea ice: types, physical and mechanical properties, heat flux, temporal and spatial distribution, melting and freezing processes, forecasting models, and remote sensing of ice/snow covered surfaces. Physical oceanography of currents and water masses, deep and bottom water formation, fronts and eddies, polynya processes, and underwater acoustics.

Operational aspects of Arctic and Antarctic meteorology, including polar lows, boundary layer and marginal ice zone influences.

Polar oceanography: Sea ice amount, seasonal distribution, melting and freezing processes, physical and mechanical properties, drift and predictions. Physical oceanography of currents and water masses, deep and bottom water formation, fronts and eddies

Course	Dual Degree
Semester	VIII
Subject Code	ESE 469
Subject Title	Ionosphere and Space Physics

Syllabus:

Unit 1: **Structure and variability of Earth's ionosphere**

Introduction to neutral upper atmosphere and its interaction with solar radiation: Thermal structure of the atmosphere, Heat balance and temperature profile of thermosphere, Dissociation and diffusive separation and thermospheric composition, Exosphere, Solar radiation at the top of the atmosphere, Attenuation of solar radiation in the atmosphere, thermal effect of radiation, photochemical effects of radiation, Airglow

Formation of ionosphere and its processes: Structure of ionosphere, Production of ionospheric layers, Chapman's theory of photoionization, Loss mechanisms and chemistry of ionospheric regions, Transport processes in the ionosphere, Electrical conductivity, plasma diffusion.

Equatorial electrodynamics: E region dynamo theory and Sq current system, Daytime equatorial electrojet, Equatorial ionization anomaly, sporadic E, F region dynamo, spread F, Prereversal enhancement, E region plasma instabilities

Unit 11: **Space Weather**

Geomagnetism: Earth as a magnet: magnetic field of the Earth, Van-Allen radiation belts, Plasmasphere, Magnetosphere, Interaction of Solar wind with the Earth's magnetosphere

Geomagnetic storms: Geomagnetic storms, Geomagnetic indices, Effects of geomagnetic storms on the Earth's upper atmosphere and ionosphere: Electric field and neutral wind disturbances

Implications of Space weather effects: Effect on satellite electronics, satellite charging, satellite drag, heating of the neutral atmosphere, Effect on radiowave propagation, effect on communications and navigational outages

Satellite Based Augmentation Systems (SBAS): Importance SBAS, WAAS, GAGAN

Course	Dual Degree
Semester	VIII
Subject Code	ESE 470
Subject Title	General Circulation and Monsoon

Syllabus:

Unit I:

Global Circulation: Differential Heating - Latitude variation of radiation balance - Meridional Temperature Gradient; Meridional Heat transport through atmosphere and ocean; Thermal Wind; Jet Stream - Baroclinicity, Angular momentum; Vorticity - Relative Vorticity, Absolute Vorticity, Potential Vorticity, Isentropic Potential Vorticity; Instability - Barotropic Instability & Rossby Waves, Baroclinic Instability & Planetary Waves; Global Winds -General Circulation of the Atmosphere, Single-cell Model, Three-Cell Model, ITCZ; Westerly Winds and the Jet Streams, Brewer Dobson circulation, Quasi-Biennial Oscillations.

Air masses and fronts: Air mass production – Classification – Sources of air masses in winter and summer and their modification. Fronts and frontal surfaces – Principal frontal zones –frontogenesis and frontolysis. Extra-tropical cyclones- formation – Life cycle – Structure and movement. Anticyclones and blocking. Heat and cold waves.

Unit II:

Monsoons (Indian, Australian, African, American): Global perspective of monsoon, CTCZ, ITCZ over Indian ocean – structure and movement, 5-7 day, 30-50 day oscillations (MJO),10-20 day oscillations.

Monsoon rain bearing systems: Monsoon trough/ CTCZ, Depressions, onset vortex,Mechanism of formation, structure and dynamics, monsoon Mesoscale process, seasonal prediction and predictability of monsoon, coupled monsoon system, the role ocean in the life cycle of Indian monsoon system

Monsoon variability: Interannual variability and decadal variability, Teleconnections of India summer monsoon with southern oscillation, El-Nino, La Nina, Indian Ocean dipole mode, NAO, Reversal of monsoon system, winter monsoon.

Tropical Cyclones (Genesis, Intensification, Evolution, Dissipation, Structure, Motion, and forecasts), Thunder storms (CAPE and CINE, Favorable conditions for severe thunderstorms, influence of vertical wind shear, stability indices, Life cycle and structure of Thunderstorm).

Course	Dual Degree
Semester	VIII
Subject Code	ESE 471
Subject Title	Land – Atmosphere Interaction Dynamics

Syllabus:

Introduction to hydrometeorology, hydrologic and bio geochemical cycles, Water vapour in atmosphere, Vertical gradients in atmosphere, Atmospheric Boundary Layer, Surface Energy balances, Sensible heat flux, Latent heat flux, heat budgets, Plant canopy interactions with the atmosphere. Evaporation, evapotranspiration and their measurements, empirical equations, potential evapotranspiration, Global carbon cycling, Leaf energy fluxes, vegetation dynamics, Canopy processes and Canopy resistance. LAI measurements using satellite remote sensing, Carbon cycle feedback to climate system, Soil vegetation Atmosphere transfer schemes. Introduction to climate system, Land – Climate interactions. Land use Land cover change, Urbanization, Effects on climate system. Application of Satellite remote sensing in LULC changes. Numerical Modelling of Land Atmosphere interaction, Subgrid scale variability of land surface features

Course	Dual Degree
Semester	VIII
Subject Code	ESE 472
Subject Title	Atmospheric and Oceanic Instrumentation and Measurement Techniques

Syllabus:

Instruments and Measurement Systems: Instrument Response, Measurement Quality, Signal to Noise ratio, Measurement Artifacts, Instrument Response Time, Instrumental Time Resolution, Detection Limit and Sensivity, Sources of Uncertainties, Calibration procedures. Basic statistics, concept of error and uncertainty analysis, Error analysis, probability distribution functions, regression analysis, least square fit, goodness of fit, uncertainties in the fit, propagation of error for a simple linear system. Measurement of meteorological variables: wind, pressure, temperature, humidity, dew point temperature and rain fall, Snow and Rain Sampling Techniques. Radar Principles, Radar equation, Various types of Radar, Estimation of rainfall from weather radar measurements

Lidars: Basic lidar principles, Various types of Lidar, Lidar probing of aerosols and clouds, Principles of Microwave Radiometers for atmospheric probing of temperature and water vapour.

Principles of Visible, IR and Microwave Remote Sensing techniques, satellite orbits and their characteristics, Spectral bands used in satellite remote sensing for aerosols, clouds and water vapour, Satellite observation geometries, determination of solar and satellite zenith angles and relative azimuth, Spectral variation of surface reflectance for different surface types and vegetation, Basic concepts of satellite remote sensing: Instantaneous field of view, pixel resolution, swath, panoramic corrections, ground track, revisit period, orbital precession, Basics of satellite data structure and formats, Levels of data processing, Basic principles for retrieval of geophysical parameters from satellite observations in different spectral bands: estimation of surface reflectance, brightness temperature, detection of clouds, estimation of aerosol optical depth, estimation of cloud top temperature, Principle of GPS technique for measurement of water vapour.

Aerosols: Measurement of aerosol optical properties: aerosol optical depth, scattering coefficient, absorption coefficient, angular scattering measurements, Measurement of aerosol physical and chemical properties: aerosol sampling, Sampling Inlet types and Sampling Efficiency, Sampling and Measurement using Inertial, Gravitational, Centrifugal, and Thermal Techniques, Thermal and Optical Transmittance (TOT) Techniques, Incandescence Methods, Methods for Chemical Analysis of Atmospheric Aerosols, Principles of Ion Chromatography, Mass Spectrometry, Optical and Electrical Mobility Methods for Particle Characterization, Principles of Airborne sampling of Aerosols.

Trace Gases: Chemiluminescence, Photochemical reaction, Chemical Conversion Techniques, Spectroscopic techniques, Satellite Instrumentation for Monitoring Trace Gases.

Clouds: Optical Techniques for the Measurement of Cloud Water Content, Cloud Probes and Imager, Cloud Particle Sampling, Cloud Particle Spectrometer with Depolarization,

Radiation: Measurement of solar radiation, radiance and irradiance, spectral radiance, measurement of shortwave and longwave fluxes, Meaurement of global and diffuse radiative fluxes, principle for converion of satellite measured radiances to fluxes using ADMs.

Oceanic Research Vessels, Expendable Bathythermograph (XBT), Optical and Infrared Imaging and altimeter system, Interferometry Techniques, CTD sonde, Acoustic Doppler Current Profiler (ADCP), Moored and Drifting **Buoys** and Satellite Instrumentation.

Master of Technology
in
Optical Engineering

Semester – VII

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

Optical field, interaction between light and matter; basic concept of reflection (specular and diffuse), refraction, transmission, absorption and scattering, speckle and its applications, coherence: temporal and spatial, van Cittert-Zernike theorem and its applications, polarized light, Stokes parameters, Jones and Muller matrices, Interferometer and its extension to polarization domain, diffraction, optical singular fields. Gaussian theory of optical system.

Basics of holography: in-line and off-axis holography, refection, white light, rainbow and guided wave holograms, polarization holography, Imaging in the random media, Incoherent imaging techniques, Imaging as an inverse problem. X-ray tomography as an example. Optical coherence tomography, Wavefront recovery from intensity measurements, Phase problem of optics, Diffuse optical tomography. Synthetic aperture radar construction and application. LIDAR, Optical microscopy: Bright field, dark field, phase contrast microscopy, confocal microscopes. Improvement of resolution using near-field optics, Fourier transforms spectroscopy, Fourier fringe analysis technique; Partial polarization, polarimetric imaging.

Text Books/References

1. “Aberrations of Optical Systems” W.T.Welford Adam Hilger,1986
2. “Principles of Optics” Max Born & Emil Wolf - Pergaman Press
3. “Applied Optics and Optical Design” –Robert R.Shannon & F.C.Wyant Academic Press.
4. “Lens design Fundamentals” Rudolf King, Academic Press
5. “Focal regions propagation, diffraction and focusing of light, sound and water waves” J. Jakob, Taylor & Francis
6. “Speckle phenomena in optics” J. W. Goodman, Robert & Company 2007
7. “Polarized light” D. H. Goldstein

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 – CO2, 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	(3 – 0 – 0) 3 credits

Basic characteristic of Optical Fiber Waveguides – Ray theory– Acceptance angle, Numerical aperture,skew rays – Electromagnetic Modes in Planar waveguides and Cylindrical Waveguides, Goos-Haenchen shift – Step index and Graded index Fibers – Single Mode and multimode fibers.

Dispersion in single mode fibers– dispersion induced limitations – dispersion management, Fiber lossesattenuation coefficient, Nonlinear optical effects-SRS, SBS, SPM – modal birefringence and polarization maintaining fibers.

Measurement Methods in Optical Fibers – attenuation, refractive index profile, numerical aperture pulse dispersion and bandwidth, cutoff wavelength, bending loss, mode field diameter birefringencemeasurements, OTDR.

Coupled mode theory and applications – coupling equations, degenerate and non-degenerate mode coupling, coupling between optical source to waveguide, fiber to fiber joints, fiber splicing, optical fiber connector between waveguides.

Optical Fiber Amplifiers – Optical amplification, Erbium doped Fiber Amplifier, Fiber Raman Amplifier,Wide band amplifiers. Optical integrated circuits.

Text Books/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 (2007)
3. Optical Fiber Communications, Gerd Keiser, Fourth Edition, Tata McGraw Hill (2008) Optical Fiber communications, J M Senior, Prentice Hall of India (1994
4. Fundamentals of Optoelectronics, C R Pollock, Irwin Inc., (1995)
5. Fiber Optic communications systems, G P Agrawal, Third Edition, Wiley Interscience (2002)
6. Integrated Optics-Theory and Technology, R G Hunsperger, Sixth edition, Springer (2009)
7. Photonics-Optical Electronics in Modern communications, A Yariv and P Yeh, Sixth edition,Oxford University Press (2007)

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 telescopes.

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 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

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 (τ). 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

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. 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.

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 Physics (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 Quantum 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 – 3) 4 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

Part 1: 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, Mermin-Wagner theorem.

Renormalization Group: scaling hypothesis and universality, renormalization group transformation. Upper and lower critical dimensions, epsilon-expansion, Ising model as example.

Quasi-long-range order, Kosterlitz-Thouless transition.

Part 2: Nonequilibrium Statistical Mechanics

Introduction to nonequilibrium, Markov Processes, Fokker Planck Equation, Langevin Equation, Master equation.

Linear response: Kubo formula, fluctuation-dissipation theorem.

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. 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.

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 (4th edition, TMH)
2. Atomic and molecular spectroscopy: basic aspects and practical applications By Sune Svanberg (4th edition, Springer)
3. Modern spectroscopy By John Michael Hollas (4th edition, Wiley)
4. Quadrupole ion trap mass spectrometry By Raymond E. March, John F. J. Todd (2nd 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 $\pi/2$ 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.