Indian Institute of Space Science & Technology (IIST)

Thiruvananthapuram

Curriculum and Syllabus for

M. Tech. in Quantum Technology

Operative from 2022 & revised in 2025

Department of Physics

Why M.Tech. in Quantum Technology?

The 20th century was witness to phenomenal advances in Physics. Besides enriching our understanding of sub-atomic and sub-nuclear physics over decades, concurrent technological developments also directly contributed in a big way to global progress. Much of the growth in living standards over the last 50 years can be singularly attributed to semiconductor electronics-based technologies. Over the years, rapid growth in these technologies has progressively resulted in faster, smaller, less power-hungry, and affordable end products. As it stands, the size of the smallest transistor today is just a few nanometers. This continued reduction in scale has also brought us to an epoch wherein we are staring at a threshold beyond which quantum features will dominantly govern the character of the devices.

As anticipated as it is inevitable, this new paradigm brings possibilities unseen and considered impossible until now. A host of technologies in a wide variety of application areas indispensable to modern living - communication, computation, sensing, and metrology, to name a few - have been entirely reworked, keeping into account the quantum rules of engagement in play. Most of these technologies have seen immense commitments towards research from both academia and industry in the past two decades, with some having crossed the stage of technology demonstration or even prototypes. For example, photonic, superconducting and atom-based quantum technologies outperform their classical counterparts. With several government labs, R&D establishments, and technology industries strongly invested in these developments, the field of quantum technologies has seen rapid growth, prompting an equivalent requirement for specialized scientific and technical human resources.

In India, national scientific establishments such as ISRO and DRDO are actively developing some of these technologies, especially quantum communication and sensing, which will be critical soon. There is also a larger national initiative from the Government of India to engage the academia, industries, and strategic research establishments, under a broader umbrella in pursuit of an early adaptation of these technologies.

The MTech in Quantum Technologies at IIST will join this global effort in preparing young engineering and science graduates, both towards industry and research, meeting the specific goals targeted by ISRO and other national scientific establishments. The outlined course work at IIST will provide a strong foundation with the required basics and give a broad overview of cutting-edge Quantum Technologies. The first semester lays the essential foundations where the student will be trained in the basics of quantum mechanics, solid state physics, optics, and experimental techniques, while simultaneously being introduced to quantum computation. In the second semester, the student covers various aspects of quantum technologies, such as quantum optical communication, quantum metrology, and quantum devices, while simultaneously being exposed to the physics of information. The student, in parallel, gets to perform several fundamental experiments as well as write elementary quantum computational codes as part of the curriculum. Apart from this, the student can choose one elective from a range of courses directly related to quantum technology in the second semester. The second year of the course is dedicated to the final year project, where the student will carry out academic as well as research and development based activity in any of the relevant quantum technology-related areas. The work carried out will have the potential to be publishable, with implications for the development and application of quantum technology.

M Tech in Quantum Technology

Program Educational Objectives (PEO)

- To train students to handle various quantum technologies-based applications required for research and industry.
- To train students with the potential for developing quantum technologies in Space Science and Development: Quantum communication, quantum cryptography, quantum sensing, etc.
- To train the students to think out-of-box of the usual curriculum through research-level projects and laboratory training.
- To develop new quantum technologies with the help of students, R&D labs, and Industries.

Program Outcomes (PO)

- We will have students with a balanced skill set in fundamental and technological aspects of quantum technologies.
- We will have skilled students trained in quantum technologies to take up challenges in communications, cryptography, sensing, computing, spectroscopy and new materials.
- Students can join cutting-edge research and advanced futuristic devices directly.
- The program will generate human resources for the quantum technology-based Space Technology research to be a value-addition to the Indian Space Research program and other national scientific establishments.

Educational qualifications for the admission:

B.E./B.Tech. in any of the disciplines in B.E./B.Tech. degree-(T999) with GATE in Electronics and Communication Engineering/Electrical Engineering/ Physics/ Computer Science and Information Technology/Data Science and Artificial Intelligence.

OR

M.Sc. in any of the disciplines in M.Sc. degree with GATE in Electronics and Communication Engineering/Electrical Engineering/ Physics/ Computer Science and Information Technology.

SEMESTER–WISE CREDITS

Semester	I	II	III	IV
Credits	17	18	15	20

SEMESTER I

Course Code	Course Name	Course Credit L-T-P-C
PH634	Fundamentals of Quantum Mechanics	3-0-0-3
PH635	Introductory Solid State Physics	3-0-0-3
PH637	Electromagnetism and Optics	3-0-0-3
PH638	Quantum Computation	3-0-0-3
PH639	Experimental Techniques and Quantum Devices	3-0-0-3
PH657	Advanced Experimental Techniques Lab	0-0-3-1
PH658	Quantum Simulation Lab	0-0-3-1
Total Credits		**17**

SEMESTER II

Course Code	Course Name	Course Credit L-T-P-C
PH643	Quantum Optics and Quantum Communication	3-0-0-3
PH644	Quantum Metrology and Quantum Sensing	3-0-0-3
PH645	Physics of Quantum Information	3-0-0-3
PHXXX	Elective 1	3-0-0-3
PHXXX	Elective 2	3-0-0-3
PH647	Quantum Electronics and Materials Lab	0-0-3-1
PH648	Quantum Photonic Technology Lab	0-0-3-1
PH649	Seminar	0-0-0-1
Total Credits		**18**

SEMESTER III

Course Code	Course Name	Course Credit
PH753	Project- Phase I	15
PH756	Comprehensive viva	2
Total Credits		**17**

SEMESTER IV

Course Code	Course Name	Course Credit
PH758	Project- Phase II	18
Total Credits		**18**

LIST OF ELECTIVES

Course Code	Course Name	Course Credit L-T-P-C
PH711	Atomic and Molecular Spectroscopy	3-0-0-3
PH712	Optical Thin Films Science and Technology	3-0-0-3
PH713	Optical and Electro-Optical Sensors	3-0-0-3
PH714	Optical Communication	3-0-0-3
PH715	Advanced Optoelectronics	3-0-0-3
PH716	Statistical and Quantum Optics	3-0-0-3
PH717	Non-Linear Optics	3-0-0-3
PH718	Quantum Many-Body Physics	3-0-0-3
PH719	Device Physics and Nanoelectronics	3-0-0-3
PH720	MEMS and MOEMS	3-0-0-3
PH721	Cold Atoms and Bose-Einstein Condensates	3-0-0-3
PH722	High Resolution NMR Spectroscopy in Solids	3-0-0-3
PH723	Solid State NMR Spectroscopy	3-0-0-3
PH724	Quantum Information Processing	3-0-0-3
AVC868	Advanced Sensors and Interface Electronics	3-0-0-3
AVD864	Computer Vision	3-0-0-3
AVD867	Pattern Recognition and Machine Learning	3-0-0-3
AVD870	Deep Learning for Computational Data Science	3-0-0-3
AVC871	Applied Markov Decision Processes and Reinforcement Learning	3-0-0-3
AVD887	Internet of Things	3-0-0-3
AVC867	Electronics System Design	3-0-0-3
MA611	Optimization Techniques	3-0-0-3
MA624	Advanced Machine Learning	3-0-0-3
AVD621	Estimation and Detection Theory	3-0-0-3
AVD872	Advanced Deep Learning	3-0-0-3
AVD873	Deep Learning: Theory and Practice	3-0-0-3
AVD874	Optimization Methods for Machine Learning	3-0-0-3
AVD879	Information Theory and Coding	3-0-0-3
AVD889	Graph Theory	3-0-0-3
AV461	Advanced Control Theory	3-0-0-3
AV474	Cryptography	3-0-0-3
MA873	Graphical and Deep Learning Models	3-0-0-3
MA867	Reinforcement Learning	3-0-0-3

SEMESTER I

PH634 Fundamentals of Quantum Mechanics 3 Credits

- Linear vector spaces - inner product space - Hilbert space - examples Vectors and Tensors: Scalars and vectors, Orthonormal basis sets, Gram-Schmidt orthonormalization, Expansion of an arbitrary vector. The Cauchy-Schwarz inequality, the triangle inequality. Isotropic tensors, Rotations in three dimensions, Proper and improper rotations, scalars and pseudoscalars, polar and axial vectors

- Group Theory: Discrete groups, cosets, factor groups, examples, Lie algebra, generators of continuous groups, examples (SU(2), SO(3), SU(3)).

- Stern - Gerlach Experiment - State vector and State space - Postulates of quantum mechanics - Time evolution - Schrodinger equation - Particle in a box, infinite well - Tunneling.

- Simple Harmonic oscillator - Creation and annihilation operators - spectrum - eigenstates

- Rotations in three dimensions, Eigen states and eigenvalues of L^2 and L_z, raising and lowering operators, Addition of angular momenta, Clebsch-Gordon coefficients.

- Time independent and time dependent perturbation theory - examples.

Textbooks and References

1. Modern Quantum Mechanics, J J Sakurai and J Napolitano, Addison Wesley Publishers
2. G B Arfken and H J Weber, Mathematical Methods for Physicists

PH635 Introductory Solid State Physics 3 Credits

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

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

- **Lattice dynamics and Specific heat:** Classical theory of lattice vibration under harmonic approximation; Vibrations of linear monatomic and diatomic lattices, 7 acoustical and optical modes, long wavelength limits; Normal modes and phonons; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity. Raman and Brillouin Spectroscopy (qualitative)

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

- **Magnetism and Superconductivity:** Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: quantum theory of paramagnetism; Ferromagnetism, Curie-Weiss law, ferromagnetic domains; Heisenberg model (introduction), antiferromagnetism and ferrimagnetism. Overview of superconductivity - Experimental survey; Zero resistance state, Meissner effect, flux quantization, London equations, penetration depth, isotope effect, specific heat. Type I and Type II superconductors. Electron-electron interaction via lattice: Cooper pairs and BCS formalism, High Tc superconductors (qualitative discussion).

Textbooks and References

- Ali Omar, Elementary Solid State Physics, Pearson
- N. Ashcroft and D. Mermin, Solid State Physics, Cengage.
- Charles Kittel, Introduction to Solid State Physics, Wiley.
- H. Ibach and H. Luth, Solid State Physics: An Introduction to Theory and Experiment, Springer.
- Solid State Physics, S.O. Pillai, New Age International Publications.
- Physics of Semiconductor Devices, S.M. Sze, Wiley Publications.
- Introduction to Superconductivity, A. C. Rose-Innes and E. H. Rhoderick, Pergamon.

PH637 Electromagnetics and Optics Credits 3

- Introduction to electrostatics and magnetostatics, Maxwell's Equations, Electrometric waves in dielectric media, reflection, refraction, transmission, absorption and scattering. Metal dielectric interface, Plasmonics.

- Ray optics, Postulates of ray optics, Simple optical components, Matrix optics, The Ray-transfer matrix.

- Paraxial wave approximation of Maxwell's Equations. Huygen's principle, Fresnel and Fraunhoffer diffraction. Imaging systems. Interference and interferometers.

- Paraxial polarization, Stokes parameters, Jones matrices.

- Lasers: Working principle, population inversion, optical resonators, three and four-level lasers, Ruby and He-Ne lasers.

- Nonlinear Optics: second and third order non-linear interactions, phase-matching, second and third harmonic generation.

- Integrated Photonics: Optical wave guide, fiber beam splitter and combiner, integrated resonators and filters, optical switching and modulators.

Textbooks and References

1. Fundamental of Photonics, by Saleh and Teich
2. Fundamental of Optics: Jenkins and White
3. Principle of Optics, by Born and Wolf
4. Optics, by Hecht
5. Introduction to Optics, Pedrotti, Pedrotti, and Pedrotti
6. Polarized Light, by Goldstein
7. Nonlinear Optics, by Boyd

PH638 Quantum Computation Credits 3

- Review of Quantum Mechanics and Motivation for Quantum Computation

- Qubit: The qubit state - matrix and Bloch sphere representation - computational basis – unitary evolution.

- Multi-qubit states - No-cloning theorem - Superdense coding - Pure states to Bell states – Bell inequalities.

- Protocols with multi-qubits: Swapping - Teleportation - gates: CNOT - Toffoli gate - NAND - FANOUT - Walsh Hadamard

- Measurement: Projective operators - General, Projective and POVM measure.

- Ensemble: Density operators - pure and mixed ensemble - time evolution - post measurement density operator.

- Composite systems: Partial trace - Reduced density operator - Schmidt decomposition - Purification- bipartite entanglement.

- Quantum computing: Classical computing using qubits - Quantum parallelism - Deutsch's algorithm -Deutsch Josza algorithm.

- Quantum circuits: Basic gates - ABC decomposition - Gray codes - Universal gates - Principle of deferred and implicit measurements - Quantum Fourier transform - applications: phase estimation, order finding - factoring, discrete logarithm and hidden subgroup problems - Role of prime factoring in classical cryptography - search algorithms.

- Quantum error correcting codes

- Physical realization of qubits.

Textbooks and Reference:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang, Cambridge University Press
2. Quantum Information and Computation, CIT Lecture Notes by J. Preskill
3. Quantum Theory: Concepts and Methods, Asher Peres, Kluwer Academic Publishers

PH639 Experimental Techniques and Quantum Devices Credits 3

- **Noise:** Various types of noise, and their origin, identification and isolation in an experimental environment. Ground, shield, Eddy currents. Differential Transmission, Modulation and Lock-in measurement techniques.

- **Vacuum technology**: Gas flow equations, flow regimes, types of pumps, gauges, and seals, choosing the right equipment. Designing a UHV system, vacuum chambers, etc. Vacuum level and quality diagnostics, Leak detection.

- **Cryogenics**: Production, detection, low and ultra-low temperatures using liquid ^{4}He, ^{3}He and dilution refrigerators. Helium cryostats.

- **Quantum electronics and Quantum logic**
    - Quantum Dots: size quantization effects, Exciton confinements, increase in the bandgap, density of states of quantum dots, quantum 2D electron gas materials.

- Quantum Conductance: ballistic transport, resistance quantization, derivation of Landauer formula, break-junction experiments. Tunnel junctions: tunnelling through single Quantum dots – Coulomb blockade phenomenon. Gated tunnel devices - Single electron transistors (SET), Coulomb diamonds, applications of SETs. Quantum dot Inverter operations.

- **Single photon sources and detectors**
  - Deterministic single-photon sources: Single atoms, ions and molecules, color centers of diamond, Quantum dots.
  - Probabilistic single-photon sources: spontaneous parametric downconversion, four-wave mixing.
  - Single photon detectors: photomultiplier tubes, single-photon avalanche photodiodes, superconducting nanowire single-photon detectors.

Textbooks and References:

1. Experimental Techniques in Condensed Matter Physics at Low Temperatures: Richardson and Smith, (2019) Boca Raton: United States.
2. Matter and Methods at Low Temperatures: Frank Pobell, (2007) Springer-Verlag Berlin Heidelberg.
3. Single Photon Generation and Detection: Physics and Applications- Migdall, Polyakov Fan and Bienfang, (2013). Netherlands: Elsevier Science.

PH657 Advanced Experimental Techniques Lab Credits 1

1) Michelsen's interferometer

2) Mach-Zehnder interferometer and complementarity test.

3) Gaussian laser beam characterization

4) Tunneling of microwaves in a wax prism.

5) Polarization spatial entanglement

6) Stokes parameter measurement (state estimation problem)

7) Scanning Tunneling microscopy (STM) imaging (principle, hardware and scanning withatomic resolution on graphite surfaces: identification of carbon atoms)

8) I-z spectra in STM: experimental validation of tunneling through an infinite potential wall,estimation of workfunction of graphite.

9) Engineering 3D CAD drawing (Solidworks), basics of workshop processes and techniques.

10) Virtual instrumentation: General purpose instrumentation and computer interface,virtual instrumentation techniques and programming using Labview.

PH658 Quantum Simulation Lab Credits 1

1) Introductions to programming. Quantum simulators for quantum circuits and algorithms using Qiskit and QuTiP;

2) Introduction to DFT, familiarization of the ATK simulation tool. Electronic structure of benzene /graphene.

3) Electronic configuration and band-structure of simple 2-dimensional materials: DFT simulations

4) Vibrational spectroscopy of simple molecules by DFT simulations: identification of Infrared and Raman modes.

SEMESTER II

PH643 Quantum Optics and Quantum Communication Credits 3

- Quantization of the Electromagnetic field, quadrature operators for fields, vacuum fluctuations and vacuum noise, uncertainty relation, number states, quantum phase, coherent states, phase space pictures of coherent states, squeezed states, photon number distributions in different states.

- Two level atom, interaction of light with matter, Jaynes-Cummings model.

- Twin-photon generation with non-linear interactions, parametric generation of light, spontaneous parametric down-conversion, optical parametric amplifiers and optical parametric oscillator.

- Linear Optics with Quantized Fields: Beam splitter transformations, single and two photon interference, Michelson and Mach-Zehnder interferometer, and Hong-Ou-Mandel dip.

- Theory of photodetection, direct, balanced, and homodyne detection

- Theory of optical coherence: Spatial and temporal coherence, van Cittert-Zernike theorem, Intensity interferometers, Hanbury-Brown-Twiss experiment, Photon-bunching and anti-bunching, quantum optical coherence.

- Experimental tools forrealization of Quantum Optical Communication: Einstein-Podolsky-Rosen (EPR) Paradox, Entangled States, EPR Pairs: Photons with correlated polarization, Measuring the polarization of a single photon,Photon pairs and joint polarization measurements, EPR pairs with correlated polarizations,Bell's inequality: CHSH Variant, Quantum random number generation,Quantum Cryptography, Experimental implementation of single and entangled photon based Quantum Key Distribution protocols: BB84 and Ekert protocol. Quantum teleportation and dense coding, Quantum communication through- free space, fibers and satellites, quality check and privacy.

Textbooks and References:

1. Introductory Quantum Optics, by Gerry and Knight
2. Quantum Optics, by G S Agarwal
3. A Guide to Experiments in Quantum Optics, by Hans and Bachor
4. Quantum Computation and Quantum Information, by Nielson and Chuang
5. Introduction to Quantum Optics: From the Semi-classical Approach to Quantized Light, by Aspect, Fabre, and Grynberg.
6. Optical quantum information processing,, by Kok and Lovett

- Introduction to estimaton theory, Bayesian methods, conditional probabilities, estimation errors, bounds on estimation errors, the Cramer-Rao inequality. Introduction to classical signals.

- Quantum states, density matrix, measurement, POVM. Probabilities in quantum mechanics, Naimark's theorem. Introduction to quantum estimation theory. Discussion on qubits, and other examples. The Quantum-Cramer-Rao inequality and bound. Estimation of a single parameter, time-energy uncertainty relation. Generalization to multi-parameter estimation.

- Quantum sensors and quantum sensing, Examples of Quantum sensors: Optical sensors based on light squeezing and photonic quantum correlations, standard quantum limit (SQL) and sensitivity beyond SQL.

- Quantum mechanical treatment of the Mach-Zehnder interferometer, the quantum advantage in interferometry: Phase estimation ininterferometers, States with enhanced phase sensitivity, NOON state, etc, atom interferometers.

- Cold atoms, Cooling of atoms, techniques, laser cooling, magneto optical traps, BEC, spectroscopy in condensates, frequency standards,quantum gyroscopes, atom interferometers, Neutral atoms as magnetic sensors, Trapped ions and Rydberg atoms as electric field sensors, atomic clocks, nitrogen-vacancy centers, superconducting sensors.

Textbooks and References:

1. Quantum detection and estimation theory, C. W. Helstrom, Academic press.
2. Probabilistic and statistical aspects of quantum theory, A. S. Holevo,North-Holland.
3. A guide to experiments in quantum optics, H. A. Bachor and T. C. Ralph,Wiley
4. Atom interferometry: Proceedings, Tino, G M [Ed.] Italian Physical Society Villa Monastero 15-20 July 2013International School of Physics "Enrico Fermi" Course 188: Proceedings.
5. The Quantum World of Ultra-Cold Atoms and Light Book II: The Physics of Quantum-Optical Devices, C Gardiner and P. Zoller, World Scientific.
6. Research papers

PH645 Physics of Quantum Information Credits 3

- Basic laws of thermodynamics. Equation of state. Potential formulation of thermodynamics. Connection between statistics and thermodynamics, Boltzmann entropy.

- Microcanonical, canonical, and Grand canonical ensembles, partition function, Gibbs state. Examples: Classical and quantum harmonic oscillator, magnetization.

- Shannon entropy, properties, entropy as information, classical data compression, Binary entropy, Relative entropy, Conditional entropy and Mutual information, Data processing inequality.

- Bipartite pure states, Schmidt decomposition, Density matrix formulation. Reduced density matrix, Qubit and quantum harmonic oscillator examples, Gibbs state, von-Neumann entropy, properties, von-Neumann entropy as measure of bipartite entanglement, detection of bipartitte entanglement, Quantum data compression, Holevo bound.

Textbooks and References:

1. Statistical Mechanics, R.K. Pathria, Elsevier Publishing.

2. Fundamentals of statistical and thermal physics, F. Reif, Levant Books, 2010

3. Quantum Computation and Quantum Information, Nielsen and Chuang, Cambridge University Press.

4. Lecture notes on Quantum Information and Computation, John Preskill.

5. Quantum concepts and methods, Asher Peres, Kluwer Publishers.

XXXXX ELECTIVE I Credits 3

XXXX ELECTIVE 2 Credits 3

PH647 Quantum Electronics and Materials Lab Credits 1

1) Scanning tunneling spectroscopy: Measurements of local density of states (LDOS) of various materials: estimation of bandgap and position of the Fermi levels

2) Fowler-Nordheim tunnelling through an insulating material: estimation of band-offsets of metals with insulators.

3) Vacuum technology: how to achieve ultra-high vacuum

4) Cryogenics: towards absolute zero

5) Sensors and analogue instrumentation.

6) Superconducting levitation, physical properties of BCS and High Tc superconductors

7) FPGA based electronics and post-processing protocols for QKD

8) Designing active filters

PH648 Quantum Photonic Technology Lab Credits 1

1) Demonstration of photon-statistics of different light sources

2) Test of Bell's inequality

3) Demo of BB84 using cryptography Kit

4) Quantum random number generation

5) Shot noise measurement of photons

6) Saturated absorption spectroscopy

7) Measurement of the numerical aperture of fibre; attenuation and dispersionin optical fibres

8) WDM Mux, Demux and add drop multiplexing

9) Fibre amplifier

PH649 Seminar Credits 1

SEMESTER III

PH753 Project- Phase I Credits 15

PH756 Comprehensive Viva Credits 2

SEMESTER IV

PH758 Project- Phase II Credits 18

SYLLABUS OF ELECTIVE COURSES

PH711 Atomic and Molecular Spectroscopy Credits 1

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

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

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

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

Text Books/References

1. Fundamentals of Molecular Spectroscopy By Banwell (4th edition, TMH).

2. Atomic and molecular spectroscopy: basic aspects and practical applications By SuneSvanberg (4thedition, 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 Wileyinter science)

5. Mass spectrometry: principles and applications By Edmond de Hoffmann, Vincent Stroobant (3rdedition, 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, Gunter Werth (Springer)

8. Physics of atoms and molecules By B. H. Bransden, Charles Jean Joachain (2nd edition PrenticeHall)

PH712 Optical Thin Films Science and Technology Credits 3

Propagation of electro-magnetic in stratified dielectric medium, Fresnel equations Optical properties ofmaterials, metals, semiconductors and dielectrics, optical glass materials in the visible and near infraredregion, 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 fordesign 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 andUltra-high vacuum techniques. Mechanical and High vacuum pumps, ultra-high vacuum pumps. Highvacuum measurement techniques, principle, calibration and electronics read out Deposition and productionof 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 quartzmicro-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. FTIRspectrometers Characterization of non-optical properties of thin films: Mechanical adhesion, abrasion andhardness. Surface characterization techniques for thin films: Surface morphology, X-ray structure, Chemicalcomposition. 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 deepspace. Radiation environment in space. Space Qualification of Optical coatings and materials. Effect ofspace environment on optical materials and thin films.

Textbooks and 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 –CRCPress – 2002 ISBN 0824708490
6. Handbook of Thin Film Technology- Leon –Imaissel&ReihardGlang –Mc Graw –Hill Book Company-1970 –ISBN 0070397422

PH713 Optical and Electro-Optical Sensors Credits 3

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

Sensor optics, Sensor instrumentation, Signal processing techniques Space craft sensors: Optical AttitudeSensors: Fiber Optic gyros [with integrated optics], Ring Laser Gyros,Star sensors – Spacecraft attitudedetermination 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 sensingsensors for Earth observation, Cartography Hyper spectral Sensors.

Modeling, design, analysis, calibration and Performance evaluation of the above. System Integration andTesting. Optical, Integrated and Fiber optic sensors: Acceleration, Displacement and Velocity sensors[anemometer], Position – linear and Angle encoders, temperature, strain etcFiber optics based smartsensors for Space applications : MOEM Sensors, Large optical Systems for space born cameraapplications.: 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, ContributorMichael J.Rycroft, Wei Shyy, Cambridge University Press, 2000

3. Spacecraft Attitude determination and Control by Computer Sciences, Corporation Attitude Systemsoperation, 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.

PH714 Optical Communication Credits 3

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 analogfibre 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, DPSKsystem 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.Sivarammurthy and Mohan Gurusamy-Prentice Hall of India, 2002

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

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

PH715 Advanced Optoelectronics Credits 3

Review of Semiconductor device Physics, Semiconductor Opto electronics- Solid State Materials, Emitters,Detectors and Amplifiers, Semiconductor Emitters- LEDs, Diodes, SLDs, CCDs, Semiconductor lasers- basicStructure, 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, GaNetc for differentwavelengths.

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. Fabricationtechniques [MBE, CVD, Lithography, Thin films technoloy] and Device characterization. IntegratedOptics-Optical wave guide theory, wave guide structures. Fiber optic interconnects- Fiber lasers andamplifiers, 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 sensorsfor measurement of temperature, pressure, stress etc for space craft health monitoring, Hydrogen leakagesensing 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.
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

PH716 Statistical and Quantum Optics Credits 3

Introduction to probability theory, properties of probabilities, random variabes andprobability distribution,generating functions, examples of probability distributions, Gaussian probability distribution, central limittheorem, 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 ofinterference, 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 stellarinterferometry.

Elementary theory of polarization of stochastic electromagnetic beams. Polarized, unpolarized, and partiallypolarized light. Partially polarized light and the degree of polarization. Stokes parameters and the Poincaresphere. Unified theory of polarization and coherence. Spectral degree of coherence and stochasticelectromagnetic 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 electromagneticfield.

Representation of a state, Fock basis expansion, coherent state expansion, diagonal representation, Wignerphase space density, and the Q function, s-ordered quasi-probability. Normal, symmetric, and anti–normalordering 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.
2. Optical Coherence and Quantum Optics, L. Mandel and E. Wolf, Cambridge University Press, 1995
3. Introduction to theory of coherence and polarization of light, E. Wolf, Cambridge University Press,2007.
4. Modern Quantum Mechanics, J. J. Sakurai, Pearson Education, 2009.

5. Optical Coherence and Quantum Optics, L. Mandel and E. wolf, Cambridge University Press, 1995.
6. Quantum Optics, D. F. Walls and G. J. Milburn, Springer, 2007.
7. The quantum theory of light, R. Loudon, Oxford university press, 2000.

PH717 Non-Linear Optics Credits 3

Nonlinear optical susceptibility, wave equation description of nonlinear optical interactions - Sum frequencygeneration, Difference frequency generation, Second Harmonic generation, Phase matching condition,

Optical parametric Oscillators, Quantum mechanical theory of nonlinear optical susceptibility- Schrodingerequation calculation, density matrix calculation. Spontaneous light scattering and acousto optics, Stimulated Brillouin Scattering, Stimulated Rayleigh Scattering, Stimulated Raman Scattering, Second harmonic generation, parametric processes, 3rd order nonlinear optics, Kerr type nonlinearities, 4-wave mixing, selffocusing collapse, optical breakdown, two beam coupling, electrooptics and photorefractive effects, opticallyinduced 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, OxfordUniversity 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

PH718 Quantum Many-Body Physics Credits 3

Second quantization: Fock space representation, creation and annihilation operators for bosons andfermions, 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

PH719 Device Physics and Nanoelectronics Credits 3

Introduction: Moore's law and technology development. International Technology Roadmap forSemiconductors (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 nMOSdevices, dissipation factor, band-diagram and degeneracy at accumulation and inversion, depletion width,Mott-Schottky plot and carrier concentration. Frequency dispersion of capacitance, correction ofhigh-frequency capacitance, interface states, parallel conductance measurements, Equivalent oxidethickness (EOT); Leakage current mechanisms through MOS devices – space charges and Child's law,Schottky emission, direct tunneling, band diagram under external field: Fowler-Nordheimtunneling, 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 atlow 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; Thresholdvoltage of a MOSFET, Sub-threshold conduction in a MOSFET, transfer characteristics, transconductanceand 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 outputcharacteristics.

Introduction to Nanoelectronics: Single molecule field effect transistors, Nanowire FET's, Single electrontransistors, Single electron tunneling (SET) devices: Coulomb blockade phenomenon. Nano-scale flashmemory 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. S. 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 Physics and Technology, Wiley Interscience.

PH720 MEMS and MOEMS Credits 3

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, &microtechnologies.

Lithography: Fundamentals. Materials such as photoresist used in lithography. Techniquessuch as using optical, electron beam,focused ion,x-ray beams. Etching and micro machining. Wet and dryetching, 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, CMOScompatible MOEMS, optics specific issues for MOEMS, micro-optics, automation and sensing, shapememory actuators, piezoelectric actuators, magnetic actuators, MOEMS related sensors, micro-opticcomponents, testing and applications.

Text Books/References

1. NodiumMaluf, “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

PH721 Cold Atoms and Bose-Einstein Condensates Credits 3

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

The Ideal Bose gas, Weakly-interacting Bose gas, Ground state energy and equation of state, Particles andelementary 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 andmomentum 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).

PH722 High Resolution NMR Spectroscopy in Solids Credits 3

Nuclear spin interactions in solids: Basic nuclear spin interactions in solids, spin interactions in highmagnetic 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 molecularreorientation.

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, arbitraryrotations 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 ofdilute spins, cross-polarization dynamics, spin decoupling dynamics.

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

Spin-Lattice relaxation in iine narrowing experiments: Spin-lattice relaxation in multiple-pulseexperiments, 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.

PH723 Solid State NMR Spectroscopy Credits 3

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 matrixrepresentation and coherences nuclear spin interactions, calculating NMR power patterns, general featuresof NMR experiments.

Essential techniques for spin–1/2 nuclei: Introduction, magic-angle spinning (MAS), high-powerdecoupling, 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 dipolarcouplings, recoupling pulse sequences, double-quantum filtered experiments, rotational resonance,techniques for measuring heteronuclear dipolar couplings, spin-echo double resonance, rotational-echodouble resonance, techniques for dipolar-coupled quadrupolar (spin–1/2) pairs, transfer of population indouble resonance, rotational echo, adiabatic passage, double resonance, techniques for measuring dipolarcouplings between quadrupolar nuclei, correlation experiments, homonuclear correlation experiments forspin–1/2 systems, homonuclear correlation experiments for quadrupolar spin systems, heteronuclearcorrelation 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-integerquadrupolar 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 anglespinning 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.

PH724 Quantum Error Correction Methods Credits 3

Introduction to Shannon entropy - classical information-classical information from measurements - von Neumann entropy - properties-subadditivity and concavity- quantum data compression - classical information in quantum mechanics- Holevo bound. Quantum Information.

Entanglement as a physical resource, teleportation, dense coding, as examples. Mixed state entanglement. Detection of bipartite entanglement, various methods. Bipartite entanglement measures. Multipartite entanglement.

Quantum noise and quantum operations - Operator-sum representation -qubit channels, decoherence. Distance measures - trace distance - fidelity, etc.

Quantum state tomography, unbiased measurements, mixed state reconstruction.

Quantum error-correction: Shor code - Quantum error correction -Stabilizer codes -fault tolerant quantum computation, decoherence free subspace.

Quantum state discrimination, error probability analysis, the quantum-Chernoff bound. Introduction to quantum illumination.

Textbooks and References:

1. Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang, Cambridge University Press
2. Quantum Information and Computation, CIT Lecture Notes by J. Preskill
3. Quantum Theory: Concepts and Methods, Asher Peres, Kluwer Academic Publishers
4. Journal papers as necessary.

AVC868 Advanced Sensors and Interface Electronics Credits 3

Introduction and Background of state-of-art sensing and measurement techniques. Contactless potentiometer (resistance-capacitance scheme) – Methodology,Interface Circuits, Overview of Flight Instrumentation.

Analog Electronic Blocks, CMRR Analysis (Non-ideal opamps) of an Instrumentation Amplifier,Linearization circuits for single-element wheatstone bridges (application to strain gauge), Direct Digital Converter for Strain gauges, Signal conditioning for Remote-connected sensor elements.

Inductive sensors and electronic circuits, Eddy-current based sensors, Synchros and Resolvers, Magnetic shielding techniques.

State-of-art Magnetic Sensors – Principle, Characteristics and Applications – Induction Magnetometer, Flux gate Magnetometer, Hall Effect Sensor, Magnetoresistance Sensors, GMR Sensors – Multi-layer and Spin Valve, Wiegand Effect, SQUID.

Case Study-1: GMR Based Angular Position Sensor, Sensing Arrangement, Linearization Electronics – Methodology, Circuit Design and Analysis.

Case study-2: Brake Wear Monitoring, Reluctance-Hall Effect Angle Transducer–Sensing Arrangement, Front-end Electronics. Overview of Basic Capacitive sensors. Various design considerations; guarding, stray fields, offset and stray capacitance, Ratio metric measurement – advantages and circuit implementations. RMS, Peak, Average Value Electronic Schemes for Capacitive Sensors, Synchronous Phase Detection – multiplier and switching type.

Case study-3: Liquid level detection – Concentric Cylindrical Plates, Plates on container walls – Dielectric and Conductive Liquids - Analysis.

Case study-4: Capacitive Angle Transducers and Front-end electronics. Piezoelectric sensors, Seismic transducers.

Introduction to MEMS, Piezoelectric, Electrodynamic and MEMS Capacitive Accelerometers, Principles of Ultrasonic sensors - Equivalent circuit and transfer function of a piezoelectric transmitter, crystal oscillator. NDT using ultrasonic and eddy-current.

Optical and Fibre Optic Sensors MEMS Pressure sensors, Vaccum-pressure estimation and important flow measurement (volume and mass flow rate) schemes, Flapper-nozzle systems. Sensing Schemes for Attitude, Position measurement and navigation, Instrumentation Systems for Occupancy Detection – Ultrasound, Inductive and Capacitive schemes. Non-contact current and voltage measurement, Newhuman vital-sign sensing techniques.

Textbooks:

1. Ramón Pallás-Areny,John G. Webster, Sensors and Signal Conditioning, 2nd Edition, Wiley, 2003.
2. Doebelin, E.O., Measurement systems: Application and Design, 5th ed., McGraw hill, 2003.

References:

1. J. G. Webster, The Measurement, Instrumentation and Sensors Handbook, Vol 1 and 2, CRC Press, 1999.
2. L. K. Baxter,Capacitive Sensors – Design and Applications,IEEE Press Series on Electronic Technology, NJ
(1997).
3. Jacob Fraden, Handbook of Modern Sensors – Physics, Designs and Applications, Springer, 4th Edition, 2010.
4. John P. Bentley, Principle of Measurement Systems, Pearson Education; 3rd Edition, 2006.
5. A. Barua, Fundamentals of Industrial Instrumentation, Wiley, 2013.

AVD864 Computer Vision Credits 3

The course is an introductory level computer vision course, suitable for graduate students. It will cover the basic topics of computer vision, and introduce some fundamental approaches for computer vision research: Image Filtering, Edge Detection, Interest Point Detectors, Motion and Optical Flow, Object Detection and Tracking, Region/Boundary Segmentation, Shape Analysis, and Statistical Shape Models, Deep Learning for Computer Vision, Imaging Geometry, Camera Modeling, and Calibration. Recent Advances in Computer vision.

Prerequisites:

Basic Probability/Statistics, a good working knowledge of any programming language (Python, Matlab, C/C++, or Java), Linear algebra, and vector calculus.

Grading:

Assignments and the term project should include explanatory/clear comments as well as a short report describing the approach, detailed analysis, and discussion/conclusion.

Course evaluation:

4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Sem 40 %.

Text Books & References

1. Simon Prince, Computer Vision: Models, Learning, and Interface, Cambridge University Press
2. Mubarak Shah, Fundamentals of Computer Vision
3. Richard Szeliski, Computer Vision: Algorithms and Applications, Springer, 2010
4. Forsyth and Ponce, Computer Vision: A Modern Approach, Prentice-Hall, 2002
5. Palmer, Vision Science, MIT Press, 1999,
6. Duda, Hart and Stork, Pattern Classification (2nd Edition), Wiley, 2000,
7. Koller and Friedman, Probabilistic Graphical Models: Principles and Techniques, MIT Press, 2009,
8. Strang, Gilbert. Linear Algebra and Its Applications 2/e, Academic Press, 1980.

Programming:

Python will be the main programming environment for the assignments. The following book (Python programming samples for computer vision tasks) is freely available. Python for Computer Vision. For mini-projects, a Processing programming language can be used too (strongly encouraged for android application development)

AVD867 Pattern Recognition and Machine Learning Credits 3

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

Text Books & References

1. Pattern classification, Duda and Hart, John Wiley and sons,2001.
2. Machine learning, T M Mitchel, McGraw Hills 1997 Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2006.

AVD870 Deep Learning for Computational Data Science Credits 3

Prerequisite: Linear algebra, Probability, and interest in programming

Description: Deep learning methods are now prevalent in the area of machine learning, and are now used invariably in many research areas. In recent years it received significant media attention as well. The influx of research articles in this area demonstrates that these methods are remarkably successful at a diverse range of tasks. Namely self driving cars, new kinds of video games, AI, Automation, object detection and recognition, surveillance tracking etc. The proposed course aims at introducing the foundations of Deep learning to various professionals who are working in the area of automation, machine learning, artificial intelligence, mathematics, statistics, and neurosciences (both theory and applications).

This is a proposed course to introduce Neural networks and Deep learning approaches (mainly Convolutional Neural networks) and give a few typical applications, where and how they are applied. The following topics will be explored in the proposed course.We will cover a range of topics from basic neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning, and applications to problem domains like speech recognition and computer vision.

Prerequisites:

a strong mathematical background in calculus, linear algebra, and probability & statistics, as well as programming in Python and C/C++. There will be assignments and a final project.

1. Introduction to Visual Computing and Neural Networks
2. Basics of Multilayer Perceptron to Deep Neural Networks with Autoencoders
3. Unsupervised deep learning: Autoencoders for Representation Learning and MLP Initialization
4. Stacked, Sparse, Denoising Autoencoders and Ladder Training
5. Cost functions, Learning Rate Dynamics and Optimization
6. Introduction to Convolutional Neural Networks (CNN) and LeNet
7. Convolutional Autoencoders and Deep CNN (AlexNet, VGGNet)
8. Very Deep CNN architecture for Classification (GoogLeNet, ResNet, DenseNet)
9. Computational Complexity and Transfer Learning of a Network
10. Object Localization (RCNN) and Semantic Segmentation
11. Generative Models with Adversarial Learning
12. Recurrent Neural Networks (RNN) for Video Classification
13. Deep reinforcement learning
14. NLP/Vision Application

Text Books & References

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville. Deep Learning.
2. Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classification. Wiley-Interscience. 2nd Edition. 2001.
3. Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008.
4. Russell, S. and Norvig, N. Artificial Intelligence: A Modern Approach. Prentice-Hall Series in Artificial Intelligence. 2003.
5. Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995.
6. Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001.
7. Koller, D. and Friedman, N. Probabilistic Graphical Models. MIT Press. 2009.

AVC871 Applied Markov Decision Processes and Reinforcement Learning Credits 3

Review of basic probability and stochastic processes. Introduction to Markov chains. Markov models for discrete time dynamic systems, Reward, Policies, Policy evaluation, Markov decision processes, Optimality criteria, Bellman’s optimality principle, Dynamic programming, Optimality equations, Policy search, Policy iteration, Value iteration. Generalized Policy Iteration, Approximate dynamic programming. Exploration versus Exploitation in Reinforcement learning, Multiarmed and Contextual Bandits, Reinforcement learning setup and Model free learning, Monte Carlo learning, Q-learning & SARSA, Temporal difference learning, Function approximation, Policy gradient methods, Actor-critic methods, Stochastic approximation and its applications to reinforcement learning, Neural networks in reinforcement learning, Deep reinforcement learning. Applications and case studies of Markov decision processes and Reinforcement Learning in Machine Learning, Control, Communication, Robotics, and Optimization.

Text Books & References

1. Richard S. Sutton and Andrew G. Barto. Reinforcement learning: An introduction. MIT press, 2018.
2. Dimitri P. Bertsekas, Dynamic programming and optimal control. Vols. I and II, Athena scientific, 2005.
3. Sheldon M. Ross. Applied probability models with optimization applications. Courier Corporation, 2013.
4. Sheldon M. Ross. Introduction to stochastic dynamic programming. Academic press, 2014.

Pre-requisites:

Undergraduate Probability and Random Processes, Programming background

AVD887 Internet of Things Credits 3

Course Objectives:

Evolution of the Internet and Big Data. Introduction to the Internet of Things (IoT). The Internet protocol stack. IPv4 and IPv6. TCP and UDP. DNS and the IoT IoT Protocol stack, Layers in the Internet of Things. Sensing and Actuator Layer, Network Layer, and Application Layer. Wireless Sensor Networks. Communication Technologies for the Internet of Things. CoAP, MQTT, and HTTP Protocols for IoT. Data aggregation and fusion. Operating Systems for IoT. Contiki OS, Tiny OS, and other IoT OSs. Databases for the Internet of things. Data mining for the Internet of Things. Block chain design for the Internet of Things. Approaches of Big data analytics for IoT. Security issues and solutions in IoT. Applications of the Internet of Things. IoT for assisted living. Case studies of IoT. Internet of Medical Things. Introduction to the Digital Twins.

Text Books & References

1. Soldatos, John –Editor, Building blocks for IoT analytics internet-of-things analytics, River publishers, 2017.
2. Perry Lea, Internet of Things for Architects: Architecting IoT solutions by implementing, Packt Publishing Limited, 2018.
3. Raj Kamal, Internet of Things, McGraw Hill Education, 2017
4. C. Siva Ram Murthy and B. S. Manoj, Ad hoc Wireless Networks: Architectures and Protocols, Prentice Hall PTR, New Jersey, May 2004.
5. B. S. Manoj, “Internet of Things,” bsmp, Trivandrum, 2022.
6. Relevant research publications.

AVC867 Electronics System Design Credits 3

Module 1: Role of Interface Electronics, Analog Electronic Blocks, OPAMP – internal structure, Open-loop gain, Input R, Output R, DC noise sources and their drifts, CMRR, PSRR, Bandwidth and stability, Slew rate, Noise – general introduction, OPAMP Circuits and Analysis - Difference and Instrumentation Amplifiers (3-opamp and 2-opamp), Effect of cable capacitance and wire-resistance on CMRR, IA with guards, Biomedical application, Current-mode IA (Howland), Current-input IA, filters, Filters with underdamped response, state-variable filters, All-pass filters, Current Sources (floating and grounded loads), PGA, V-to-f converters, Negative Resistance Generator, Gyrator, GIC and applications, Quadrature oscillator, Introduction to switched capacitor circuits and applications, OTA and applications.

Module 2: Frequency and Time Measurement, Sample Hold Circuits, ADCs and their properties, Different ADC Architectures – Single Slope, Dual Slope (with emphasis on DMM), SAR, Flash, Sigma-Delta. Voltage references and regulators,

Module 3: Basic electronic design concepts - potential divider, component packages, burden/loading effects, Error budgeting – Zener drift, resistance drift, voltage offsets and bias current errors, Transistor as amplifier – Basic circuit, loading effects; transistor as a switch – Darlington pairs, drivers, high-side drives, transistor latch.

Module 4: Analog controllers – temperature controller, error amplifier, integral controller, PI controller, PID controller, system TC Vs sensing TC.

Module 5: Transistor (linear) voltage regulator – over current protection, fold-back protection, voltage regulator with bypass, heat-sink design, regulator design with LDOs, current sources – high side loads, grounded loads with reference wrt. Ground, current sources with 3 pin regulator ICs, 4-20mA current transmitters, loop powered circuits.

Module 6: Special topics: PLL, isolation amplifiers, gate drivers, oscilloscope probes (gain selection circuits), techniques for power management.

Text Book & References

1. Ramón Pallás-Areny, John G. Webster, *Sensors and Signal Conditioning*, 2nd Edition, Wiley, 2003
2. Sergio Franco, Design with Operational Amplifiers and Analog Integrated Circuits, 3rd Edition, McGraw hill, 2002
3. Ramón Pallás-Areny, John G. Webster, *Analog Signal Processing*, 1st Edition, Wiley, 2011
4. George Clayton, Steve Winder, “Operational Amplifiers”, 5th Edition, Elsevier Newnes, 2003
5. Ramakant A. Gayakwad, “Opamps and Linear Integrated Circuits,” PHI India, 4th Edition
6. *L. K. Baxter, Capacitive Sensors – Design and Applications, IEEE Press Series on Electronic Technology, NJ (1997)*
7. John P. Bentley, *Principle of Measurement Systems*, Pearson Education; 3rd Edition, 2006
8. Horowitz, P., & Hill, W. (2015). *The art of electronics* (3rd ed.). Cambridge University Press.

MA611 Optimization Techniques Credits 3

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**:** sim- plex methods, duality in linear programming, transportation problem; nonlinear programming: Lagrange multiplier, KKT conditions, convex programing.

Text Books & References

1. Chong, E. K. and Zak, S. H., An Introduction to Optimization, 2nd Ed., Wiley India (2001).
2. Luenberger, D. G. and Ye, Y., Linear and Nonlinear Programming, 3rd Ed., Springer (2008).
3. Kambo, N. S., Mathematical Programming Techniques, East-West Press (1997).

MA624 Advanced Machine Learning Credits 3

Kernel Methods: reproducing kernel Hilbert space concepts, kernel algorithms, multiple kernels, graph kernels; multitasking, deep learning architectures; spectral clustering; model based clustering, independent component analysis; sequential data: Hidden Markhov models; factor analysis; graphical models; reinforcement learning; Gaussian processes; motiff discovery; graph based semisupervised learning; natural language processing algorithms.

Text Books & References

1. Bishop, C. M., Pattern Recognition and Machine Learning, Springer (2006).
2. Hastie, T., Tibshirani, R., and Friedman, J., The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer (2002).
3. Cristianini, N. and Shawe-Taylor, J., An Introduction to Support Vector Machines and other kernelbased methods, Cambridge Univ. Press (2000).
4. Scholkopf, B. and Smola, A. J., Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond, The MIT Press (2001).
5. Sutton R. S. and Barto, A. G., Reinforcement Learning: An Introduction, The MIT Press (2017).
6. Goodfellow, I., Bengio, Y., and Courville, A., Deep Learning, The MIT Press (2016).
7. Koller D. and Friedman, N., Probabilistic Graphical Models: Principles and Techniques, The MIT Press (2009).

AVD621 Estimation and Detection Theory Credits 3

Estimation Theory, Maximum Likelihood estimation (MLE): exact and approximate methods (EM, alternating max, etc), Cramer - Rao lower bound (CRLB), Minimum variance unbiased estimation, Sufficient Statistics, Best Linear Unbiased Estimation, Large and Small Sample Properties of Estimators, Bayesian Inference and Estimation - MMSE, MAP Estimation, Wiener and Kalman filtering (sequential Bayes), Detection Theory: Likelihood Ratio testing, Bayes detectors, Minimax detectors, Multiple hypothesis tests Neyman - Pearson detectors (matched filter, estimator - correlator, etc), Wald sequential test, Generalized likelihood ratio tests (GLRTs), Wald and Rao scoring tests.

Assessment: The course will feature two midterms and a final exam. There will be continuous evaluation using class tests, problem sets, and programming assignments.

Textbooks and References

1. Fundamentals of Statistical Signal Processing: Estimation Theory (Vol 1), Detection Theory (2), .M. Kay's, Prentice-Hall Signal Processing Series, 1993
2. Linear Estimation, Kailath, Sayed and Hassibi, Prentice-Hall Information and Sciences Series, 1 st edition, 2000.
3. Statistical Signal Processing (Paperback) by Louis Scharf, 1 st edition,
4. An Introduction to Signal Detection and Estimation, Poor, H. Vincent, Springer Text in Electrical
Engineering, 1994
5. Detection, Estimation, and Modulation Theory –Part I, H.Van Trees, et.al, 2 nd edition, Wiley.
6. Monte Carlo Strategies in Scientific Computing, J.S. Liu, Springer - Verlag, 2001. Stochastic

AVD872 Advanced Deep Learning Credits 3

The course include following topics

- Introduction to Neural network and Backpropagation
- Basics of Tensorflow and Keras
- Details on Convolutional Neural Networks and types of different convolutions
- recent topics in Recurrent Neural Networks, LSTM, GRUs
- Time series Processing
- Details of Transformer Networks for text and Vision
- Instance and Semantic Segmentation
- Generative Models, VAE
- Deep Generative Adversarial Networks
- Model Interpretation etc.

Prerequisites: Linear Algebra, Probability random process, Machine Learning OR permission of the instructor.

Assessment: Midterms (30%), end sem (40%) and programing Assignment, homework, quizzes course project (30%)

References

1. Ian Goodfellow, Yoshua Bengio and Aaron Courville (2016) *Deep Learning*, ISBN-13: 978-0262035613, MIT Press
2. Recent Papers

AVD873 Deep Learning: Theory and Practice Credits 3

The Perceptron, Feed-forward networks and Multi-layer perceptron, Memory based networks like Boltzmann Machines, Hopfield Networks. State based networks like Recurrent Neural Networks, Long Short Term Memory Networks. Convolutional Neural Networks, Bidirectional networks, Concept based networks used for transfer learning, Structural Networks for structured prediction, Attention based networks, Auto encoders for dimension reduction and embedding, Generative Adversarial

Networks, Deep Gaussian Processes, Deep Bayesian nets, Deep Search Models, Deep Reinforcement Learning, Deep Neural Recommenders. Non-convex Optimization tools for Deep Networks. Theoretical tools to describe Convolutional Neural Networks and Recurrent Neural Networks. Learning theory for Deep Neural Networks. Several Applications covering image analytics, forensic, computer vision, natural language processing, speech processing and data analytics.

Assessment: Midterms (30%), end sem (40%) and programing Assignment, homework, quizzes course project (30%)

References

1. Ian Goodfellow, Yoshua Bengio and Aaron Courville (2016) *Deep Learning*, ISBN-13: 978-0262035613, MIT Press
2. recent Papers

AVD874 Optimization Methods for Machine Learning Credits 3

Introduction (ML applications)-topics in Linear system (linear regression)- Basics of Gradient Descent and its variants (logistic regression)-A detailed understanding of Projected Gradient (white-box adversarial attack) and Proximal Gradient (lasso)-Details of Conditional Gradient (recommendation system)-The Subgradient approach (svm)- Mirror Descent and Metric Gradient methods - Acceleration (total variation denoising)- Smoothing (robust svm)-optimal transport for machine learning - Alternating (VAE)- Minimax (adversarial training)-Averaging (GANs)-Splitting (federated learning)-Extragradient (max entropy)-Stochastic Gradient (Boltzmann machine)- Variance Reduction (boosting)- Derivative-free (black-box adversarial attack)

Pre requisites

Knowledge of linear algebra, multivariate calculus, basic analysis and basic probability. interstate in numerical computing or machine learning. Knowledge of programming in either Python.

Assessment: Midterms (30%), end sem(50%) and programing Assignment, homework , quizzes course project (20%)

References

1. First-order and Stochastic Optimization Methods for Machine Learning. Guanghui Lan. Springer, 2020
2. Algorithms for Optimization. Mykel J. Kochenderfer and Tim A. Wheeler. The MIT Press, 2019.
3. First-Order Methods in Optimization. Amir Beck. SIAM, 2017.

AVD879 Information Theory and Coding Credits 3

Information theory: Information – Entropy, Information rate, classification of codes, Kraft McMillan inequality, Source coding theorem, Shannon - Fano coding, Huffman coding, Extended Huffman coding - Joint and conditional entropies, Mutual information - Discrete memoryless channels – BSC, BEC – Channel capacity, Shannon limit. Channel Capacity**-** AWGN channel, colored noise channel, Wireless Channel-SIMO MISO, MIMO channel, Error control coding –Block codes Definitions and Principles:

Hamming weight, Hamming distance, Minimum distance decoding - Single parity codes, Hamming codes, Repetition codes - Linear block codes, Cyclic codes - Syndrome calculation, Encoder and decoder, BCH codes,CRC codes, RS codes, Decoding Techniques for RS codes, LDPC encoder and decoder, Performance analysis of RS and LDPC codes. Polar Codes: polar encoder and decoder, performance analysis of polar codes – Convolution codes: Linear convolution encoders, Structural properties of Convolution codes, Viterbi decoding technique for convolution codes – Soft / Hard decision, concatenation of block codes and convolutional codes, performance analysis, concept of Trellis coded modulation. Turbo Codes: Parallel concatenation, Turbo encoder, Iterative decoding using BCJR algorithm, Performance analysis.

References:

1. Information Theory and Coding, Norman Abramson, McGraw-Hill, 1963
2. Digital Communications, John Proakis & Masoud Salehi, 5th edition McGraw-Hill, 2008.
3. Introduction to Error Control Codes, S Gravano, Oxford University Press 2007
4. The theory of Information theory and coding, Robert McEliece, Cambridge University Press, 2002
5. Shu Lin and Daniel. J. Costello Jr., “Error Control Coding: Fundamentals and applications”, Prentice Hall Inc.
6. R.E. Blahut, “Theory and Practice of Error Control Coding”, MGH.
7. W.C. Huffman and Vera Pless, “Fundamentals of Error-correcting codes”, Cambridge University Press.
8. Rolf Johannesson, Kamil Sh. Zigangirov, “Fundamentals of Convolutional Coding”, Universities Press (India) Ltd.
9. Sklar, ‘Digital Communication’, Pearson Education.

AVD889 Graph Theory Credits 3

Introduction to Graphs and their applications. Finite and infinite graphs. History of graph theory. Paths and Circuits. Isomorphism, sub graphs. Walks, paths, and circuits. Hamiltonian paths and circuits. Trees and Fundamental Circuits. Cut-Sets and Cut-Vertices. Connected and disconnected graphs and components. Directed Graphs. Euler graphs. Operations on graphs. Graph-Theoretic Algorithms and Computer Programs. Applications of Graph theory in operations research. Distributed graph algorithms for computer networks. Complex networks. Regular networks, random networks, small-world networks, and scale-free networks. Advanced graph theory concepts.

References:

1. Narsing Deo, Graph Theory with Applications to Engineering and Computer Science, PHI Learning Private Limited, New Delhi, 2010.
2. B. S. Manoj, Abhishek Chakraborty, and Rahul Singh, "Complex Networks: A Networking and Signal Processing Perspective," Pearson, New York, USA, February 2018.
3. Robin Wilson, Introduction to graph theory, Noida Pearson Education 1996.
4. Nora Hartsfield, Pearls in graph theory a comprehensive introduction, New York, 1990.
5. V. K. Balakrishnan, Schaum's outline of theory and problems of Graph theory, Tata McGraw
Hill Publishing Co. Ltd., New Delhi, 2004.
6. Kayhan Erciyes, Distributed Graph Algorithms for Computer Networks (Computer Communications and Networks), Springer, June 2013.

AV461 Advanced Control Theory Credits 3

State space Approach: State space modeling of physical systems – diagonal and Jordan canonical forms - Solution of Linear Time Invariant (LTI) state equation – Cayley Hamilton theorem – Controllability and Observability Tests – Kalman decomposition technique -Controller design by state feedback – Full order/reduced order observer design – observer based state feedback control - stability definitions in state space domain. Adaptive control theory: System Identification – Frequency – Impulse – Step Response methods –Off-line – on line methods – Least square – Recursive least square – fixed memory – stochastic approximate method. MRAS & STC: The gradient approach – MIT rule Liapunov Functions – Pole placement control – minimum variance control – Predictive control.

Text Books:

1. Karl.J.Astrom, Bjorn Witten Mark, Adaptive Control, 2nd Ed., Pearson Education Pvt. Ltd.
2. M.Gopal, 'Digital Control Systems and State Space Method', 3rd Ed., TMH, 2008.

References:

1. Katsuhiko Ogata, 'Modern Control Engineering', PHI -India, New Delhi 1989.
2. Fairman, 'Linear Control Theory: State Space Approach', John Wiley, 1998.
3. John S. Bay, 'Fundamentals of Linear State Space Systems', McGraw Hill, 1998.
4. Isermann R, 'Digital Control System vol. I & II', Narosa Publishing House, Reprint 1993.
5. Mendal JM, 'Discrete Technique of Parameter Estimate', Marcel Dekkas, New York, 1973.

AV474 Cryptography Credits 3

Introduction to number theory – Symmetric key and Public key crypto systems which includes pseudorandom functions and permutations, block ciphers, symmetric encryption schemes, security of symmetric encryption schemes, hash functions, message authentication codes (MACs), security of MACs, PKI, public-key(asymmetric) encryption, digital signatures, security of asymmetric encryption and digital signature scheme. Chaos base cryptography systems – quantum computing – introduction to smartcard technology.

Text Books & References:

1. William Stallings, "Cryptography and Network Security – Principles and Practices", Pearson Education, Third Edition, 2003.
2. Behrouz A. Foruzan, "Cryptography and Network Security", Tata McGraw-Hill, 2007
3. Bruce Schneier, "Applied Cryptography", John Wiley & Sons Inc, 2001.
4. Wade Trappe and Lawrence C. Washington, "Introduction to Cryptography with coding theory, Pearson Education, 2007.
5. Wenbo Mao, "Modern Cryptography Theory and Practice", Pearson Education, 2007.
6. Thomas Calabrese, "Information Security Intelligence: Cryptographic Principles and Applications", Thomson Delmar Learning,2006.

MA873 Graphical and Deep Learning Models Credits 3

Graphical Models: Basic graph concepts; Bayesian Networks; conditional independence; Markov Networks; Inference: variable elimination, belief propagation, max-product, junction trees, loopy belief propogation, expectation propogation, sampling; structure learning; learning with missing data. Deep Learning: recurrent networks; probabilistic neural nets; Boltzmann machines; RBMs; sigmoid belief nets; CNN; autoencoders; deep reinforcement learning; generative adversarial net- works; structured deep learning; applications.

References:

1. Koller D. and Friedman, N., Probabilistic Graphical Models: Principles and Techniques, The MIT Press (2009).
2. Barber, D., Bayesian Reasoning and Machine Learning, Cambridge Univ. Press (2012).
3. Bishop, C. M., Pattern Recognition and Machine Learning, Springer (2006).
4. Hastie, T., Tibshirani, R., and Friedman, J., The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer (2002).
5. Murphy, K. P., Machine Learning: A Probabilistic Perspective, The MIT Press (2012).
6. Goodfellow, I., Bengio, Y., and Courville, A., Deep Learning, The MIT Press (2016).

MA867 Reinforcement Learning Credits 3

The reinforcement learning problem; tabular & approximate solution methods: dynamic programming, Monto-Carlo Methods, temporal difference learning, eligibility traces; planning and learning; dimensions of reinforcement learning.

References:

1. Sutton R. S. and Barto, A. G., Reinforcement Learning: An Introduction, The MIT Press (2017).
2. Tesauro G., Temporal Difference Learning and TD-Gammon, Communications of the Association for Computing Machinery (1995).