COURSE STRUCTURE

SEMESTER – 1		L	T	P	Credit
MAI T11	Mathematical Techniques	3	1	0	4
MAI T12	Foundations of Applied Optics	3	1	0	4
MAI T13	Image Science	3	0	0	3
MAI T14	Astrophysical Concepts	3	0	0	3
MAI P11	Optical Testing and Metrology	0	0	6	6
MAI P12	Sensors (include lab-view, detectors, CCD characterization)	0	0	6	6
MAI S1	Seminar I	0	0	2	2
	Total	12	2	14	28
SEMESTER - 2					
MAI T21	Optical and Photonic Systems, Components and Devices	3	1	0	4
MAI T22	Lasers, Optical Fiber and thin film	3	0	0	3
MAI T23	Digital Image Processing and Numerical analysis	3	0	0	3
MAI T24	Optical Instrumentation	3	1	0	4
MAI P21	Lens Design and Thin film	0	0	6	6
MAI P22	Analog & Digital Image Processing, Digital holography	0	0	6	6
MAI S2	Seminar II	0	0	2	2
	Total	12	2	14	28
SEMESTER - 3					
MAI T31	Topic-to be decided a. Stellar interferometry b. Radio Interferometry	0	5	0	5

	c. Radio telescopes d. Photon-detection techniques in Radio, X-ray and γ-ray astronomy. e. Solar-Adoptive Optics, polarimeter, cooling of primary mirror f. Embedded Systems, FPGAs, Digital I/O cards, PCB designing				
MAI INT	Internship at Indian Institute of Astrophysics	0	0	10	10
MAI DP	Dissertation (Preliminary)	0	0	5	5
	Total	0	0	20	20
SEMESTER – 4					
MAI DF	Dissertation (Final)	0	0	20	20
MAI GV	General Viva Voce	0	0	4	4
	Total	0	0	24	24
	GRAND TOTAL	**24**	**4**	**72**	**100**

MAI T11 : Mathematical Techniques

Vector space and matrices, linear independence, bases dimensionality, Inner product, tensors, transformations of, parallel transport, linear transformation matrices, inverse, orthogonal and unitary matrices, independent element of a matrix, Eigen values and Eigen vectors, diagonalization, complete orthonormal sets to functions, series, convergence tests;

Complex Variables, Cauchy- Riemann condition, analytic functions, Cauchy's theorem, Cauchy integral formula, Laurent series, singularities, residue theorem, contour integration, evaluation of definite integrals.

Differential equations, second order linear ODEs with variable coefficients, Solution by series expansion, non-homogeneous differential equations and solution by the method of Green's functions with applications. Eigenvalue methods, up to Strum-Liouville systems.

Special functions, Legendre, Bessel, Hermite and Laguerre functions with their physical applications, generating functions, orthogonality conditions, recursion relations,

Integral transforms, Fourier integral and transforms, inversion theorem, Fourier transform of derivatives, convolution theorem,

Laplace Transform(LT), LT of Derivatives, Inverse LT, Fourier series; properties and applications, discrete Fourier transform.

Coordinate systems, precession, time, heliocentric corrections; methods of observation, resolution, methods of data reduction,

Mathematical Methods for Physicists : G.Arfken & H.G.Weber

Advanced Engineering Mathematics : E.Kresjig

Fourier Transform and Its Applications : R.N.Bracewell

Systems and Transforms with Applications in Optics : A.Papoulis

Special Functions for Scientists and Engineers : W.W.Bell

An Introduction to Modern Astrophysics : B.W.Carrol & D.A.Ostlie

Astrophysical Concepts : M.Harwit

An Introduction to Astrophysics : Baidyanath Basu

Astronomical Physics : Stars and Galaxies : K.D.Abhayankar

The Sun : An Introduction : M.Stix

Stellar Atmospheres : D.Mihalas

MAI T12 : Fundamentals of Wave Optics

Maxwell equation of electromagnetic waves, Propagation through free space, Guided wave and waveguides,

Light as E.M.Wave, Huygen – Fresnel principle for light propagation, geometrical theory of propagation of light, Eikonal equation for propagation of light in homogeneous and inhomogeneous media.

Diffraction: Occurrence of diffraction, Scalar wave approximation, Integral theorem of Helmholtz and Kirchoff, Kirchoff's scalar diffraction theory, Fresnel diffraction, Frounhoffer diffraction and Fourier optics, Rayleigh-Sommerfield Formulation

Interference : Conditions for interference, Methods of Beam Division, Fringe Localization, Classical two-beam Interferometry – Fizeau, Michelson, Twyman-Green, Mach-Zehnder, Shearing, Multiple Beam Interferometry – Fabry-Perot, Phase Shifting Interferometry

Polarization : Polarization of plane waves – Superposition of polarized wave – Birefringence Jones matrix formalism – Stoke's parameter – Mueller Matrix formalism – Poincare sphere – Polarization devices in optics : – Polarizer – Retarders – Rotators – Optical isolators – Nicol Prism – Wave plates – Babinet's compensator – Soleil's compensator – Berek's compensator

Electromagnetic Waves : E.C.Jordan & K.G.Balmain

Electromagnetics for Engineers : A.T.Adams

Microwave Devices : P.R.Karmel, G.D.Collef & R.L.Camisa

Polarized Light : W.H.Shurcliff

Polarized Light : Fundamentals and Applications : E.Collett

Principles of Optics : M.Born & E.Wolf

MAI T13 : Theory of Optical Design

Coherence : Physical origin of line widths, Temporal and spatial coherence, Coherent scattering and dispersion, Propagation of mutual coherence, Degree of coherence, Van Cittart-Zernike theorem, Application of coherence theory to astronomy.

Ray-Optical theory of image formation: Paraxial approximation, Optical invariants, Doppler shift and its consequence

Aberration measure : Ray and wave aberrations – interrelationship – reference sphere, Power series expansion for axially symmetric systems, Aberration types and orders, Zernike circle polynomials, Chromatic aberration, Secondary spectrum

Diffraction theory of image formation : Airy pattern, Two-point resolution, Rayleigh criterion of resolution, Point spread function of aberrated system, Aberration tolerances, Strehl ratio, Marechal criterion, Aberration balancing, System theoretic viewpoint of image formation, principles of superposition, Space invariance and isoplanatism, Optical transfer function, Modulation transfer function, Phase transfer function, Factor of encircled energy, Merit function.

Principles of Optics : M.Born & E.Wolf

Modern Optics : E.B.Brown

Astronomical Optics : D.J.Shroeder

Optics : E.Hecht

MAI T14 : Astrophysical Concepts

Overview of the major contents of the universe, Sun and stars, stellar interiors, HR diagram, nuclear energy generation, neutrino astronomy, white dwarfs and neutron stars, plasma processes, compact objects, shape, size and contents of our galaxy, basics of stellar dynamics, normal and active galaxies, gravitational wave astronomy, high energy physics, Newtonian cosmology, microwave background, early universe

Astronomy fundamentals, Black body radiation, Radiation mechanism, Flux density and luminosity, basics of Radiative transfer and Radiative processes, Magnitudes, Motions and Distances of Stars : Absolute stellar magnitude and distance modulus, Bolometric and radiometric magnitudes, Colour-index and luminosities of stars, Stellar positions and motions, Velocity dispersion, Statistical and moving cluster parallax, Extinction, Stellar temperature, Effective temperature, Brightness temperature, Color temperature, Kinetic temperature , Excitation temperature, Ionization temperature, Spectral Classification of stars, stellar atmospheres. Radiative Transfer, Continuous emission, Line formation, Molecular spectroscopy

An Introduction to Modern Astrophysics : B.W.Carrol & D.A.Ostlie

Astrophysical Concepts : M.Harwit

An Introduction to Astrophysics : Baidyanath Basu

Astronomical Physics : Stars and Galaxies : K.D.Abhayankar

The Sun : An Introduction : M.Stix

Stellar Atmospheres : D.Mihalas

An Introduction to the Study of Stellar Structures : S.Chandrasekhar

Spherical Astronomy : W.M.Smart

MAI T21 : Detection Techniques in Astronomy

Detectors, Photo-electric effect, Photon Detectors : Classification – Photomultiplier – Photoconductive cell – PN / PIN / Schottky / Avalanche photodiodes – Performance Criterion – Noise consideration – Figure of merit – Array of Detectors – CCD and their characteristics parameter sensitivity, noise, quantum efficiency, spectral response, Johnson noise, signal to noise ratio, background, aberrations, detectors at different wavelengths, calibration, CCD, CMOS, Correlation measurements– Image Converters – Image Intensifiers.

Thermal Detectors – Thermopile – Thermistor – Pyroelectric, Golay cell – Thermal Imaging

Photometric Consideration in Optical Imaging systems

Optical Components & Subsystems : Optical Flats and Wedges, Prisms – Porro, Penta, Amici, Dove, Cube-Corner, Rhomboid, Pechan, Leman prisms

Eye-pieces – Huygens, Ramsden, Kellner

Objectives – Gratings – Mirrors

MAI T22 : Lasers, Optical Fibre and Thin Film Technology

Characteristics of Laser Light : Directionality – Brightness – Monochromaticity –Spatial and Temporal Coherence, Light-Matter Interaction : Spontaneous Emission – Stimulated Emission – Stimulated absorption – Einsteins' Relations – Induced Transition Rate for Two-level System – Line Shape Function – Homogeneous and Inhomogeneous Broadening - Operational Characteristics of Lasers : Three-level and Four-level Lasers – Gain and Gain Saturation, Paraxial Ray Propagation : Ray Tracing – Application to Optical Cavities – Stability – Stable and Unstable Cavities – Repetitive rays – Initial Conditions - Gaussian Beam : Stationary and Travelling TEM modes – Solution of wave equation – Physical Description of TEM_{00} Mode – Higher Order Modes – ABCD Law for Gaussian Beams - Optical Resonators : Gaussian Beam in Stable Resonators – Mode Volume – Resonance – Sharpness of Resonance – Photon Life Time – Cavity with Gain

Optical Fibres : Structure and waveguiding fundamentals, Mode theory for optical propagation, Fibre types, signal degradation : attenuation, dispersion, mode coupling, Pulse broadening

Thin Film Technology : Concept – Structure – Formation and nucleation, Fresnel coefficient – Matrix equation of single layer film – Extension to multilayer film – Transmission and absorption equations, Herpin index evaluation – Vectorial representation of thin film assembly – Absentee layers – Metallic layer and boosted reflection, Single layer and multi layer antireflection coating – Neutral mirrors and beam splitters – Polarizing beam splitters – Dichoric mirrors – Heat reflecting mirrors – Cold mirrors – Laser mirrors

MAI T23 : Digital Image Processing and Numerical Analysis

Digital Image Processing : Digital Image Acquisition: Sampling and quantization; spatial, grey level and temporal resolution, CCIR and RS170 monochrome standards, output signal organization and voltage levels.

Image Histogram: significance and interpretation.

Spatial domain Processing: Pixel point processing: linear and piecewise linear transformations, log and power law transformations, histogram equalization, Arithmetic and logic operation between image frames.

Pixel Group Processing: Convolution in spatial domain, low frequency and high frequency filtering, gradient filters.

Frequency Domain Processing: Relation with spatial domain convolution, standard low pass and high pass spatial domain filters

Morphological operations: Translation, Reflection, Complement, Difference, Dilation, Erosion, Opening and Closing, Hit or miss transform, Boundary extraction, Region filling.

Colour Image Processing: RGB and HIS colour models and interrelation, pseudocolour intensity slicing, colour segmentation.

Image Compression Standards: Lossy and lossless compressions, BMP, TIFF & JPG image formats.

Numerical Analysis : Numerical techniques, errors and error propagation, numerical integration and interpolation, random numbers, numerical solutions of algebraic, ordinary differential and partial differential equations. Probability distribution: Binomial, Gaussian, Poisson and Lorentzian distributions, regression, linear correlation coefficient, ki square distributions..

MAI T24 : Astronomical Instrumentation

Telescope : Concepts – Catoptric and dioptric systems – Cassegrain System – Schmidt system – Erecting systems

Optical Range Finder, Autocollimator

Interferometer : Fizeau-Stephan interferometer, Michelson stellar interferometer

Monochromator, Spectrometer, Spectro-polarimeter.

Spectroscopic Imaging : Grating equations, Blazed gratings, Angular and linear dispersions, spectral resolution, Littrow spectrograph, Czerny-Turner spectrograph, Monochromator, Echelle spectrograph, Observational Spectroscopy, Related Instrumentation, Spectroscopy data reduction and analysis.

Optical aperture synthesis – single aperture and multiaperture synthesis.

Theory of atmospheric turbulence, Basic formulations of atmospheric turbulence, Turbulent flows, Inertial subrange, Structure functions of the velocity field, Kolmogorov spectrum of the velocity field, Statistics of temperature fluctuations, Refractive index fluctuations, Imaging in randomly inhomogeneous media Seeing-limited images, Atmospheric coherence length, Atmospheric coherence, Aniso-planatism.

Adaptive Optics : Basic principles, Elements of adaptive optics systems, Wavefront sensors, Wavefront reconstruction, Reference source, Multi-conjugate adaptive optics

Space based telescopes, orbit, pointing, jitter, remote sensing