REGULATIONS

M.TECH.-PH.D. PROGRAM IN ASTRONOMICAL INSTRUMENTATION

jointly conducted by

DEPARTMENT OF APPLIED OPTICS AND PHOTONICS, UNIVERSITY OF CALCUTTA
and
ARYABHATTA RESEARCH INSTITUTE OF OBSERVATIONAL SCIENCES (ARIES), NAINITAL.

General

1a The Department of Applied Optics and Photonics, University of Calcutta (**AOP,CU**) AND Aryabhatta Research Institute Of Observational Sciences (**ARIES**), an autonomous body under Department of Science and Technology, Govt. of India, shall provide an academic curriculum leading towards the Integrated M.Tech-Ph.D. (Tech). Degree in Astronomical Instrumentation.

1b For successful completion of the Integrated M.Tech- PhD (Tech) programme, a candidate shall have to complete the M.Tech course work of the Integrated M.Tech-PhD (Tech) programme and have to acquire the requisite grades to be considered for the Ph.D. component of the programme. The duration of M.Tech course work will be of 2 years divided into 4 semesters, each semester being of 6 month duration. After successful completion of the M.Tech course a student can opt for registration for PhD (Tech) programme, subjected to a selection procedure and minimum cut-off grade. The PhD(Tech) programme will be conducted according to the guidelines of the University of Calcutta Ph.D. Regulations 2016.

Admission criteria and selection

2a A candidate passed with a three years B.Tech. degree in Optics and Optoelectronics / Radio Physics and Electronics from the University of Calcutta or B.Tech / BE degree in Electrical/ Instrumentation/ Electronics and Communications /Computer Science & Engineering/ Mechanical Engineering from an institution recognized by AICTE is eligible for admission to the first semester of the said Integrated M.Tech.-PhD(Tech) degree course in Astronomical Instrumentation.

2b A candidate with M.Sc. degree in Physics / Electronic Science / Applied Mathematics from a UGC recognized institution is also eligible for admission to the said course.

2c Candidates will be selected through a written examination/interview as decided on year to year basis. The entrance examination will be conducted by the ARIES. Representative(s) from the AOP, CU shall be on the examination committee and on the interview board.

M.Tech course work

3a The M.Tech course work of 100 credits is spread over 4 semesters of two years duration as per the following scheme ;
9 Theoretical Papers of total 37 credits including 4 tutorial credits
5 Practical Papers of total 30 credits
2 Seminar of total 4 credits
Dissertation work in two parts : Preliminary of 5 credits and Final of 20 credits
General Viva Voce of 4 credits

3b The CREDIT assigned to each Theoretical, Practical, Tutorial, Seminar, Internship and General Viva Voce and the corresponding teaching hours to be devoted per week are indicated in the following table. Internship and Dissertaion work shall be carried out at the ARIES.

Paper	Hours per week	Full CREDIT assigned
Theoretical	1	1
Practical	3	2
Tutorial	1	1
Seminar	[for 1st and 2nd Semester only]	1
Internship	15 [for 3rd Semester only]	10
Dissertation: Preliminary and Final	Partly in 3rd Semester and during Entire 4th Semester	10 + 20
General Viva Voce	-	4

3c Number of lecture hours per week for each theoretical and tutorial paper and number of hours per week for practical papers along with seminars and project work are as indicated in the M.Tech course structure and detailed syllabus attached herewith (Appendix 1)
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3d A candidate will get full credit for a paper provided he/she prosecutes regular full time course of studies in the AOP,CU for the first two semesters and at the ARIES, Bangalore for the next two semesters maintaining at least 65% of attendance in theoretical, practical classes, internship and successfully completes the corresponding examination according to the criterion stated below.

M.Tech Examination and evaluation procedures

4a A candidate has to earn a total of 100 CREDITs to complete the entire M.Tech. Course.

4b Examinations will be held at the end of each semester on all papers included in the syllabus of that semester. The examination will be referred to as M.Tech. Semester - (I, II, III and IV) examination, as the case may be.

4c The study leave after the completion of regular classes and before the commencement of examination will generally be of 10 calendar days.

4d Examination of a Theoretical paper carrying 3 credits will be of 3 hour duration.
Papersetters and examiners for theoretical papers will be appointed by a board of examiners consisting of (a) all faculty members of the AOP,CU (b) the honorary / guest lecturers, if any, (c) teachers associated with the course work from the ARIES, who will be treated as internal examiners.
Grades to be awarded for theoretical papers will have a component of continuous assessments to be evaluated by the teacher(s) assigned for that class work. Methodology for continuous assessment and weights will be decided by consensus opinion at the Board of Examiners meeting.
Evaluation of tutorial papers will be done by the teacher assigned for the class. Procedure of evaluation will be at his/her discretion.

5a Evaluation of a Practical paper to be conducted at the AOP,CU for the first two Semesters and at ARIES Nainital for the third Semester will be based on the performance of a candidate along with a viva voce at the end of the semester and on the report of the experiments conducted. Corresponding allocation of marks are as follows :
50% for the performance.
40% for viva voce
10% on the submitted report
Sessional work will be evaluated by the teacher(s) concerned.
Evaluation of the report and the viva voce will be conducted by a board consisting of at least two faculty members including guest faculty, if any.

5b Each candidate shall have to deliver two open session seminar talks, one each during the I-st and II-nd Semesters. His/her performance shall be assessed by a board consisting of at least five examiners including at least one form Institute of Astrophysics.

5c Each candidate has to undergo an internship at various laboratories of the ARIES to earn his credits to be awarded by a group of three examiners from the ARIES .

5d Each candidate will be assigned a topic for his/her dissertation work at the beginning of the III rd Semester to be conducted at ARIES. The student has to carry out the work independently under the supervision of a faculty member from ARIES or under the joint supervision of faculty members of AOP, CU and ARIES.
At the end of III rd Semester, each candidate will have to submit through the respective supervisors, the Preliminary Dissertation Report. The Preliminary Dissertation Work will be evaluated at the end of the semester for his/her performance during the course of the work by his/her supervisor and through an oral presentation and viva voce conducted at the ARIES, by a Board consisting of at least four Examiners of whom at least one should be from the AOP,CU.
At the end of IV-th Semester, each candidate shall have to submit a Dissertation on the assigned topic independently and shall be required to defend his/her

dissertation in an open seminar. A report (three copies) on Dissertation has to be submitted on or before a stipulated date.
50% of the stipulated full credit will be set apart for his/her performance during the course of his/her work which will be evaluated from his/her performance during the course of the work by his/her supervisor. Rest 50% of the credits marks will be evaluated in an open defence by a 5 member Board of Examiners consisting of teachers from the AOP,CU and ARIES along with one External Examiner.

5e At the end of IV-th Semester, each candidate shall have to appear at a General Viva Voce test to be conducted by a Board of Examiners consisting of four Faculty Members from AOP,CU and ARIES, along with one External Examiner.

6a The performance of a candidate in any theoretical or practical or tutorial papers, seminar, internship dissertation work and general viva voce will be awarded in terms of GRADE and GRADE POINTS earned by the candidate. The equivalence between GRADE, GRADE POINT and PERCNTAGE MARKS (out of stipulated full marks) is given below :

Percentage of marks	GRADE	GRADE POINTS
≥ 90%	Ex	10
≥ 80% but < 90%	A	09
≥ 70% but < 80%	B	08
≥ 60% but < 70%	C	07
≥ 50% but < 60%	D	06
< 50%	F	00

GRADE – F implies failure to earn minimum required CREDITs. GRADEs higher than F indicate successful completion of the subject and the candidate will earn the corresponding GRADE POINT.

6b [a] The overall performance of a candidate who earns all the credits in a particular [j^{th} , $1 \le j \le 4$] Semester examination in one chance, will be assessed by the SEMESTER GRADE POINT AVERAGE (SGPA) $\rightarrow$ $S^{(j)}$ to be computed as follows :

$$S^{(j)} = \frac{\sum_i P_i^{(j)} C_i^{(j)}}{\sum_i C_i^{(j)}}$$

where P_i stands for the GRADE POINT earned by the candidate and C_i stands for the corresponding CREDIT in a specific i^{th} course, whereas $\sum_i C_i^{(j)} = C^{(j)}$ is the total CREDIT of the j^{th} Semester.

[b] On completion of the entire course when 100 CREDITs have been earned by any candidate the CONSOLIDATED GRADE POINT AVERAGE (*CGPA*) will be computed from the following formula :

$$CGPA = \frac{\sum_{j=1}^{6} S^{(j)} C^{(j)}}{\sum_{j=1}^{6} C^{(j)}} = \frac{\sum_{j=1}^{6} S^{(j)} C^{(j)}}{100}$$

7a II-nd to IV-th Semester class will begin after a week of recess on completion of the previous Semester Examination.

A candidate will be automatically allowed to continue in the following Semesters (from II-nd to IV-th) provided he/she earns at least 20 CREDIT in the previous semester.

If a candidate earns less than 20 CREDITs in any semester, he/she will be considered as failed in that semester examination. A failed candidate will not be allowed to continue in the next semester and will have to revert to the same semester in the next academic session.

If a candidate fails to earn CREDITs for any particular topic, he/she will have to earn those CREDITs in a supplementary examination to be conducted during the currency of subsequent semester. He/She fails again to earn credit in the supplementary examination, he (she) will have to sit for regular examination of the next semester for the back papers only. Total chances to clear the credits will be limited to three. Attendance in the classes corresponding to the back CREDIT(s) is not mandatory.

The total 'back' CREDITs carried by any candidate at any stage should not exceed 8 credits. If at the end of any semester the accumulated 'back' CREDIT of any student exceeds 8, he/she will not be allowed to pursue the course further. After earning the 'back' CREDIT within the stipulated chances he/she will be allowed to continue the course.

In order to complete the M.Tech. course, a candidate will have to utilize all allowed chances within 3 consecutive academic sessions or 6 consecutive Semesters from the date of admission to the M.Tech course.

A candidate who fails to earn all the CREDITs of the M.Tech. course within the allowed chances will be treated as failed and will not be allowed to continue the course.

7b After evaluation of all examinations in each Semester (I-IV), the syndicate shall publish separate lists of candidates in the following manner .

The first list will show the results of the candidates who have earned all Semester CREDITs in the first chance and are allowed to continue in the next Semester. The list will show the SGPA earned by the candidates.

The second list will show the results of the candidates who have earned at least 20 CREDITs in the first chance but not stipulated CREDITs and are allowed to continue in the next Semester. SGPA of such candidates will not be computed and hence, will not be displayed in the list.

The third list showing the results of the candidates who appeared in the examination only to earn back CREDIT.

GRADE SHEETs showing the GRADE POINTs and the CREDITs earned will be issued to each candidate at the end of each Semester.

7c After evaluation of all the examination of IV-th Semester, the syndicate shall publish separate lists of candidates in the following manner.

The first list will show the results of the candidates who have earned all IV-th Semester CREDITs in the first chance along with the corresponding SGPA earned.

The second list will show the results of the candidates who failed to earn all CREDITs of the IV-th Semester.

The third list will show the results of the candidates who appeared in the IV-th Semester only to earn back CREDITs.

7d The final list of the M.Tech. Examination will show the results of the candidates, in order of merit, who earned all the CREDITS of the entire M.Tech. course in a single and first chance on the basis of the combined results of all 4 Semester examinations along with the corresponding CGPA earned.

The final second list will show the results of the candidates who earned all the CREDITs of the entire M.Tech. course that includes back CREDITs in at least one topic of the entire M.Tech. course along with the corresponding CGPA earned.

A consolidated GRADE SHEET, showing the combined results of all four Semester examinations of M.Tech. course will be issued to a candidate after earning all CREDITs of the entire course. The candidates who have completed the course in more than four Semesters will have to apply for the consolidated GRADE SHEET by submitting copies of all the Semester GRADE SHEETs.

Options for discontinuation and termination at the end of M.Tech course

8a A candidate may opt out of the Integrated M.Tech-PhD (Tech) programme after his /her M.Tech. examination and he/she will be awarded a the Degree of "*Master of Technology in Astronomical Instrumentation in collaboration with the ARIES*" under the seal of the University of Calcutta, mentioning the corresponding CGPA earned.

8b A candidate will be allowed to continue the Integrated course if he/she (a) attain a minimum cutoff CGPA (to be decided on year to year basis) and (b) if he/she is recommended by a selection committee on the basis of an interview. The selection committee will have representatives from the AOP,CU and ARIES.

Continuation of Integrated M.Tech-PhD(Tech) programme and award of degree

9a Selected candidates for the Integrated M.Tech-PhD(Tech) programme will have to obtain registration for the Ph.D. (Tech.) degree within one year of the publication of M.Tech result. The approval for granting registration will be guided by the prevailing regulations of Ph.D. (Tech.) degree of the University.

9b As per the provision of clause no 4.4 of the Ph.D. regulation, a Ph.D. committee in Astronomical Instrumentation shall be constituted by the Vice Chancellor in consultation with the Faculty councils of Engineering and Technology to recommend the registration of a candidate for PhD (Tech.)

9c Supervision, submission and evaluation, Viva Voce and the award of the Integrated M.Tech-Ph.D. (Tech) degree shall be guided by respective clauses of the 2016 Ph.D. regulations of Calcutta University

9d A diploma in the following format, under the seal of the University and signed by the Vice-Chancellor will be given to each successful candidate at the annual convocation of the University subsequent to the award of the Ph.D degree.

"This is to certify that (name of the awardee) obtained the degree of *"Integrated Master of Technology and Doctor of Philosophy (Technology) in Astronomical Instrumentation"* under the Faculty Council of Engineering and Technology of this University in the year (year of admittance of the degree)."

Structure of 2-year 4-semester M.Tech. Course in Astronomical Instrumentation, jointly conducted by Department of Applied Optics and Photonics, University of Calcutta and ARIES, Nainital.

SEMESTER - 1		**L**	**T**	**P**	**Credit**
AMAI T11	Mathematical Techniques	3	1	0	4
AMAI T12	Fundamentals of wave optics	3	1	0	4
AMAI T13	Image Science	3	0	0	3
AMAI T14	Astrophysical Concepts	3	0	0	3
AMAI P11	Optical Testing and Metrology	0	0	6	6
AMAI P12	Sensors (include lab-view, detectors, CCD characterization)	0	0	6	6
AMAI S1	Seminar I	0	0	2	2
	Semester Total	**12**	**2**	**14**	**28**
SEMESTER - 2					
AMAI T21	Optical and Photonic Systems, Components and Devices	3	1	0	4
AMAI T22	Lasers, Optical Fiber and thin film technology	3	0	0	2
AMAI T23	Digital Image Processing and Numerical analysis	3	0	0	3
AMAI T24	Optical Instrumentation (AO, telescope, spectrograph)	3	1	0	4
AMAI P21	Lens Design and Thin film	0	0	6	6
AMAI P22	Analog & Digital Image Processing, Digital holography	0	0	6	6
AMAI S2	Seminar II	0	0	2	2
	Semester Total	**12**	**2**	**14**	**28**
SEMESTER - 3					
AMAI T31	Optional paper (three to be choosen) **(a)** Introduction to Astronomical Instrumentation **(b)** Basic data handling (optical to infrared): Photometry, polarimetry **(c)** Embedded Systems, FPGAs, Digital I/O cards and PCB designing **(d)** Strength of material and material properties, optomechanical design **(e)** Advanced Digital System Design **(f)** Antenna theory and design: **(g)** GIS and Digital Image Processing (DIP):	9	0		9
AMAIP-31	Hands-on Instrumentation based on AMAI T31	0	0	6	6
AMAI DP	Dissertation (Preliminary)	0	0	5	5
	Semester Total	**9**	**0**	**11**	**20**
SEMESTER - 4					
AMAI DF	Dissertation (final)	0	0	20	20

AMAI GV	General Viva Voce	0	0	4	4
	Semester Total	**0**	**0**	**24**	**24**
	GRAND TOTAL	33	4	63	100

DETAILED SYLLABUS

Detailed Syllabus of 2-year 4-semester M.Tech. Course in Astronomical Instrumentation, jointly conducted by Department of Applied Optics and Photonics, University of Calcutta and ARIES, Nainital.

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 :BaidyanathBasu
- 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 : Image Science

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 foraxially 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 :BaidyanathBasu
- 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 : Optical and Photonic Systems, Components and Devices

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 TEM00 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, chi square distributions..

MAI T24 : Optical 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

MAI T31:- Optional Paper

(a) Introduction to Astronomical Instrumentation

Design of large optical telescopes, Principles of astronomical instrumentation for imaging, spectroscopy and polarimetry, Description of modern instruments on major ground based telescopes, optical system design & analysis concepts of astronomical instruments Optical reflective coatings & coating techniques.

(b) Basic data handling (optical to infrared): Photometry, polarimetry

(c) Embedded Systems, FPGAs, Digital I/O cards and PCB designing

Embedded Controller: Basics of micro-controllers, PIC, ATmega and ARM controllers. Motion Controllers and digital IO's, Uses of micro-controllers in astronomy, FPGA: Fundamentals of FPGA, Verilog and VHDL Programming, Application of FPGA in astronomy: CCD, Adoptive Optics and sensors, PCB Design:PCB design using Eagle, Deep Trace and Orcad, Simulation and analysis of electronic circuitry using Pspice

(d) Strength of material and material properties, optomechanical design

(e) Advanced Digital System Design

(f) Antenna theory and design:
Introduction to computational methods for Electromagnetics, Basic antenna theory and antenna application, Wire & loop antenna, Antenna array, Introduction to high power amplifier, Design of high-power phased antenna array for remote sensing application, Introduction to optimization algorithm for array analysis, Application of antenna in astronomical and weather research, Practical overview of antenna parameters

(g) GIS and Digital Image Processing (DIP):
Basic of remote sensing, Introduction to GIS, Digital filtering techniques, Introduction to Digital Image Processing (DIP), Application of DIP in GIS, DIP Techniques and application of deep learning,programming of DIP using MATLAB and Python