

GENERAL SYLLABUS / PREREQUISITES

PLEASE NOTE: This document is a general guideline for those who wish to study physics on their own. Before beginning right away with the books mentioned here, we recommend you, please read the preface of any books you choose. That should give you a good idea of the current understanding and whether it is suitable or not at the given stage.

XCAR / XCQR¹

1 Basic Physics

1.1 Electromagnetics

Electromagnetic Theory Coulomb's law, Electric fields and potential. Principle of Superposition. Electric Dipoles, field of a dipole. Gauss's Law. Electric current. Ampere's law. Biot-Savart's law. Faraday's law. Equation of continuity, displacement current, Maxwell's Equations. Scalar and Vector potentials, Coulomb and Lorentz gauge. Electromagnetic waves. Poynting Theorem.

Text / Reference Books

- Introduction to Electrodynamics by David Griffiths.
- Foundations of Electromagnetic Theory by J R Reitz and F J Milford.

1.2 Classical Mechanics

Transformations Generalized Coordinates, Canonical transformations, Conditions for canonical transformation and problem, Poisson brackets, invariance of PB under canonical transformation, Rotating frames of reference, inertial forces in rotating frames.

Text / Reference Books

- Classical Mechanics by H.Goldstein, Narosa Publishing Home, New Delhi.
- Classical Mechanics by N.C.Rana and P.S.Joag, Tata Mc-Graw Hill Publishing Company, Limited, New Delhi.
- Introduction to Classical Mechanics by R.G.Takawale and P.S.Puranik, Tata Mc-GrawHill Publishing, Company Limited, New Delhi.
- Classical Mechanics by J.C.Upadhyaya, Himalaya Publishing House

¹depending upon the research division chosen some topics can be omitted.

1.3 Statistical Physics

Statistical Mechanics, Entropy and Probability, Liouville's theorem (Classical), Ensembles, Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Fermi energy, Mean energy of fermions at absolute zero, Fermi energy as a function of temperature, Electronic specific heat, Compressibility of Fermi gas, Bose-Einstein Condensation.

Text / Reference Books

- Statistical Mechanics by K.Huang, John Willey and Sons (2nd Edition).
- Statistical Mechanics by Satya Prakash, Kedar Nath Ram Nath Publication (2008).
- Statistical Mechanics by Loknathan and Gambhir.
- Statistical Mechanics by Landau and Lifshitz.

1.4 Basics Relativity

Relativity and Application Concept of Special Theory of Relativity, Lorentz Transformation, Length Contraction and time dilation, Relativistic addition of velocities, conservation of mass and momentum, Concept of General Theory of Relativity, Equivalence of mass and energy, Relativistic Doppler shift and aberration of light. Lagrangian and Hamiltonian of relativistic particles, Relativistic degenerate electron gas.

Text / Reference Books

- Special Theory of relativity by Resnik.
- The Lighter side of Gravity by J. V. Narlikar.

1.5 Mathematical Method for Physics

1. **Ordinary Differential Equation:-** Ordinary differential equations Definition, order, and degree of a differential equation. First and second-order homogeneous and nonhomogeneous differential equations with constant and variable coefficients, Bernoulli Equation. The Superposition Principle. Solution by power series method due to Frobenius method. Solutions of Legendre's, Bessel's, Laguerre's and Hermit's differential equations.
2. **Partial Differential Equation:-** Partial differential equations Solutions by the method of separation of variables. Wave equation in one and two dimensions, Poisson's and Laplace's equations and Heat Conduction (or Diffusion) equation and their solutions. Solution of Euler's differential equation, Riccati equation, Euler-Cauchy differential equation.
3. **Special Functions:-** Special functions The Hermite Polynomials, One-dimensional Linear Harmonic Oscillator, Solution of Hermite's Differential Equation, Rodrigues formula, Gamma, Beta, Legendre and Associated Legendre Polynomials, Laguerre Polynomials and Bessel functions of the first kind and their properties.
4. **Fourier Series:-** Fourier Series and Transforms Definition of Fourier Series and expansion of a functions of x . Extension of interval. Advantages of Fourier series. Complex form of Fourier series. Fourier's integrals. Fourier transform and their inverse. Transforms of Derivatives, Parseval's relation. Use of Fourier transform in solving some simple definite integrals.

Text / Reference Books

- Shepley and Ross: Differential Equations.
 - Piper and Harvill: Applied Mathematics for Engineers and Physicists.
 - J.Irving and Mullineus: Mathematics in Physics and Engineering.
 - V.I.Awmianoc translated by D.E.Brown: A course of Higher Mathematics Vol-IV.
 - I.N. Sneddon: Fourier series.
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- Charlie Harper: Introduction to Mathematical Physics.

1.6 Introduction to Astronomy and Astrophysics

Sky coordinates and motions: Earth Rotation - Sky coordinates - seasons - phases of the Moon - the Moon's orbit and eclipses - Kepler's Laws - Gravity; Light & Energy - Telescopes - Optics - Detectors; Planets: Formation of Solar System - planet types - planet atmospheres - extrasolar planets; Stars: Measuring stellar characteristics (temperature, distance, luminosity, mass, size) - HR diagram - stellar structure (equilibrium, nuclear reactions, energy transport) - stellar evolution; Galaxies: Our Milky Way - Galactic structure - Galactic rotation - Galaxy types - Galaxy formation; Cosmology: Expansion of the Universe - redshifts - supernovae - the Big Bang - history of the Universe - fate of the Universe.

Text / Reference Books

- BW Carroll & DA Ostlie, An Introduction to Modern Astrophysics, Latest Edition, Addison-Wesley.
- Frank Shu, The Physical Universe, Latest Edition, University Science Books
- Martin Harwit, Astrophysical Concepts, Latest Edition, Springer.
- T. Padmanabhan, Invitation to Astrophysics, Latest Edition, World Scientific Publishing Co.

1.7 Computational Astrophysics

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

Text / Reference Books

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

1.8 Cosmology

Principles of Relativity: Overview of Special Relativity - spacetime interval and Lorentz metric four vectors - Introduction to general relativity (GR) - equivalence principle - notions of curvature - gravitation as a manifestation of the curvature of spacetime - gravitational redshift and clock corrections - orbits in strong gravity, light bending and gravitational lensing - the concept of horizon and ergosphere, hydrostatic equilibrium in GR - gravitational radiation. Cosmological Models: Universe at large scales – Homogeneity and isotropy – distance ladder – Newtonian cosmology - expansion and redshift - Cosmological Principle - Hubble's law - Robertson-Walker metric - Observable quantities - luminosity and angular diameter distances - Horizon distance- Dynamics of Friedman- Robertson-Walker models: Friedmann equations for sources with $p=wu$ and $w = -1, 0, 1/3$, discussion of closed, open and flat Universes. Physical Cosmology and Early Universe: Thermal History of the Universe - distribution functions in the early Universe - relativistic and nonrelativistic limits - Decoupling of neutrinos and the relic neutrino background - Nucleosynthesis - Decoupling of matter and radiation - Cosmic microwave background radiation (CMB)- Anisotropies in CMB - Inflation – Origin and growth of Density Perturbations - Formation of galaxies and large scale structures - Accelerating universe and type-Ia supernovae - The Intergalactic medium and reionization.

Text / Reference Books

- Cosmological Physics, Cambridge University Press, J . A. Peacock
- An Introduction to Relativity, J. V. Narlikar, Cambridge University Press.
- Theoretical Astrophysics, Volume III: Galaxies and Cosmology, T. Padmanabhan, Cambridge University Press, 2002 (for lectures on Cosmology)
- Classical Theory of Fields, Vol. 2, L. D. Landau and E. M. Lifshitz, Oxford: Pergamon Press, 1994 (For more material on General Relativity).
- Introduction to Cosmology, J. V. Narlikar, Cambridge University Press, 1993 (For the lectures on Cosmology).

2 Further Interest

1. Planetary Sciences:- 1. Fundamental Planetary Science: Jack Lissauer & Imke de Pater (Latest Edition) - Cambridge University Press 2. The Solar System: Therese Encrenaz and Jean-Pierre Bibring (Latest Edition) - Astronomy and Astrophysics Library, Springer
2. Radiation Processes in Astrophysics:- 1. G.B. Rybicki and A.P. Lightman, Radiative Processes in Astrophysics, Wiley. 2. F.H. Shu, The Physics of Astrophysics vol I: Radiative Processes, University Science Books.
3. Astronomical Techniques:- 1. C.R. Kitchen, Astrophysical Techniques, CRC press. 2. M.Longair, High Energy Astrophysics vol 1, Cambridge University Press.
4. Structure and Evolution of Stars:- 1. R. Kippenhahn and A. Weigert, Stellar Structure and Evolution, Springer. 2. A. Weiss et al, Cox and Giuli's Principles of Stellar Evolution, Cambridge Scientific Publishers. 3. Dina Prialnik, An introduction to the theory of stellar structure and evolution, Cambridge University Press. 4. S. Chandrasekhar, An Introduction to the Study of Stellar Structure, Dover.
5. Galaxies (Structure, Dynamics, and Evolution):- 1. L.S. Sparke and J.S. Gallagher, Galaxies in the Universe, Cambridge University Press. 2. J. Binney and S. Tremaine, Galactic Dynamics, Princeton University Press. 3. J. Binney and M. Merrifield, Galactic Astronomy, Princeton University Press. 4. A.K. Kembhavi and J.V. Narlikar, Quasars and Active Galactic Nuclei: An Introduction, Cambridge University Press.

6. High Energy Astrophysics:- 1. M. Longair, High Energy Astrophysics, vol. 1 and 2, Cambridge University Press 2. F. Melia, High Energy Astrophysics, Princeton University Press 3. Ya B. Zeldovich and I.D. Novikov, Relativistic Astrophysics, vol. I, Stars and Relativity
7. Formation of Stars and Planets:- 1. The Formation of Stars by S. W. Stahler and F. Palla, 2004 – Wiley – VCH 2. The Origin of Stars and Planetary Systems, 1999, eds. C.J. Lada and N.D. Kylafis 3. Protostars and Planets V, 2007, eds. B. Reipurth, D. Jewitt, and K Kell 4. Accretion Processes in Star Formation, 1998, L. Hartmann 5. Astrophysics of Planet Formation, 2010, P. Armitage
8. Advanced Astronomical Imaging:- 1. Electronic Imaging in Astronomy: Detectors and Instrumentation - Ian S. McLean, Springer, 2008 2. Adaptive Optics for Astronomical Telescopes - John W. Hardy, Oxford Series in Optical & Imaging Sciences, 1998 3. Astrotomography: Indirect Imaging Methods in Observational Astronomy, Editors: H.M.J. Boffin, D. Steeghs, J. Cuypers, Springer Lecture series, 2001
9. High Redshift Universe:- 1. The Early Universe (Frontiers in Physics): Edward Kolb, Michael Turner, Westview Press, 1994. 2. The Physics of the Cosmic Microwave Background: Pavel D. Naselsky, Dmitry I. Novikov and Igor D. Novikov, Cambridge Astrophysics Series - 41. 3. Galaxies in the Universe: Linda Sparke, John Gallagher, Cambridge University Park
10. Radio Astronomy:- 1. J. D. Kraus: Radio Astronomy. 2. Mukul R. Kundu: Solar Radio Astronomy 3. Bernard F. Burke and F. Graham-Smith: An introduction to Radio Astronomy (3rd edition) 4. Alan Sandage and others: Galaxies and the Universe 5. Thomas L. Wilson, Kristen Rohlfs, Susanne Huttemeister: Tools of Radio Astronomy (5th edn) 6. Jeff Lashley: The Radio Sky and How to Observe It
11. Exoplanets & Astrobiology:- 1. Exoplanets: Detection, Formation, Properties, and Habitability by John W Mason, Springer 2. Extrasolar Planets by Cassen, Patrick, Guillot, Tristan, Quirrenbach, A. Queloz, D.; Udry, S.; Mayor, M.; Benz, W. (Eds.), SAAS Fee Advance Course 31, Springer 3. An introduction to Astrobiology by I. Gilmour and M.A. Sephton, Cambridge University Press.

3 XCSR/DCSR

3.1 Eligibility

- Any research enthusiast who is currently in 2nd year or higher with well acquainted research methodologies and having experience in the field are preferred.
- Her/His college ranking should be under Top 50 NIRF Ranking of engineering. Knowledge of either coding language or any GUI softwares such as ANSYS, COMSOL, MATLAB, SIMULINK etc , is required.
- Students with the prerequisite understanding in their field of research interest would be highly appreciated.
- For students who are interested in fluid and heat related study, it is required from your side to have a basic idea about numerical methods.

3.2 Syllabus

- **Design/Thermal fluid/Manufacturing:**
The syllabus you have covered till now, together with any of the simulation programs or coding is required.
- **Electrical/EC:**
Python, MATLAB Programming, MATLAB Simulink, Basics of Electrical Circuits.
- **Chemistry:**
Green Chemistry, Environmental Chemistry, Bio-solar Grids, Biomass and Fuel Cell Renewable Technology.