**Syllabus for the Pre-PhD course work**

An additional 2 credit compulsory course syllabus is proposed as directed by the Dean, School of Physical Sciences, NEHU. The course is titled as Research and Publication Ethics (RPE). This course is as suggested and framed by the UGC, New Delhi. However, for uniformity, each Unit (1 credit) will be of 12 hours class duration (instead of suggested 15 hours). Once this course is approved and included the Pre-PhD course work will consist of 10 credits of compulsory courses and 4 credits of an optional course. The overall course structure and syllabus details are given below for the consideration of the present Board of Studies of Physics.

**Pre-Ph.D. (Physics) course structure**

**No. of credits = 14**

**Code No. Name of Course Credit**

 PHYCC51 Statistical and Numerical Methods in Physics 4

 PHYCC52 Experimental Techniques and their Applications 4

 PHYCC53 Research and Publication Ethics 2

 PHYOC54 Advanced Statistical Mechanics 4

 (Optional)

 PHYOC55 High Energy Physics 4

 (Optional)

 PHYOC56 Laser Physics 4

 (Optional)

 PHYOC57 Nuclear Physics 4

 (Optional)

 PHYOC58 Atomic, Molecular and Optical Physics

 (Optional) 4

Note: A candidate has to take 3(three) compulsory courses (PHYCC51, PHYCC52 and PHYCC53) totaling 10 credits and one optional Course of 4 credits

**Statistical and Numerical Methods in Physics (PHYCC51)**

Unit I : (a) Evaluation of derivatives of a function when values are given at discrete

 (equal) intervals.

 (b)` Interpolation schemes (overview), Lagrange interpolation scheme in

 detail. Evaluation of approximate derivatives using Lagrange interpolations. 12

Unit II : Programming and Numerical implementation of derivatives:

 (Algorithm and Program). 12

Unit – III : Monte-Carlo Method: Introduction, probability and Monte-Carlo simulations. Monte-Carlo averages and error bars. Monte-Carlo techniques for physical systems. Simple sampling Monte-Carlo, importance sampling Monte-Carlo with examples. 12

Unit – IV : Probability: Fundamental probability laws, General properties of distributions.

 Multivariate Gaussian distribution. Fitting of experimental data. Stochastic variables and functions, Covariance and correlations. Central limit theorem. 12

 **Books and References**:

1. Mathematical Methods by Mathew and Walker. W.A. Benjamin, 1970

2. Monte-Carlo Methods K.P.N. Murthy. University Press, 2004

3. Statistical Mechanics, Fundamentals and Modern Approach, R.E. Wilde, S. Singh, John Wiley, 1998.

4. Computational Mathematics, B.P. Demidovich and I.A. Maron, Mir Publishers, Moscow, 1981 (Chs. 14 and 15).

5. Mathematical Statistics by S.C.Gupta and V.K.Kapoor, Sultan Chand & Co, 2013

**Experimental Techniques and their Applications (PHYCC52)**

Unit - I : (With Electron and X-rays)

 Electron and X-ray diffraction (From Crystals and Liquids), X-ray

 Fluorescence (XRF), Particle-Induced X-ray Emission (PIXE),

 Electron Probe Micro Analysis (EPMA),Rutherford Back-Scattering (RBS). 12

Unit - II : (With Nuclear Particle/Radiation)

 Neutron diffraction (From Crystals and Liquids), Neutron Activation

 Analysis (NAA), Tracer Technique Gamma Ray Spectroscopy, Multi-Channel Analysiers (MCA) for pulse analysis, Alpha-Track Etch Detection 12

Unit – III : (With Longer Wave-Length Radiations)

 Production Techniques of UV/Visible, Microwave, IR radiations.

 Spectroscopic Techniques: IR,FTIR, UV-VIS, Raman. 12

Unit – IV : Familiarization/Overview of (and interaction on) the ( Ph.D.) research

 Topic with the respective thesis advisor(s) 12

**Books and references:**

1. Nuclear Physics, Principles and application by J.S.Lilley, John Wiley and Sons(2001)

2. Measurement, Instrumentation and Experimental Design in Physics and Engineering

 By Michael Sayer and AbhaiMansingh, Preitice-Hall India(2000)

3. Techniques for Nuclear and Particle Physics Experiments by William R.Leo,Springer(1994)

4. Concept of Nuclear Physics by BennardL.Cohen, Tata McGraw Hill (1974)

5. Solid State Nuclear Trace detection by S.A.Durani and R.K.Bull ,Pergamon Press(1987)

**RESEARCH AND PUBLICATION ETHICS (PHYCC53)**

Unit I. (12)

Philosophy and Ethics: Introduction to philosophy: definition, nature and scope, concept, branches; Ethics: definition, moral philosophy, nature of moral judgements and reactions.

Scientific Conduct: Ethics with respect to science and research, Intellectual honesty and research integrity, Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP), Redundant publications: duplicate and overlapping publications, salami slicing, Selective reporting and misrepresentation of data.

 Publication Ethics : definition, introduction and importance; Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.; Conflicts of interest; Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types; Violation of publication ethics, authorship and contributor ship; Identification of publication misconduct, complaints and appeals; Predatory publishers and journals.

Unit II. (12)

Open Access Publishing: Open access publications and initiatives; SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies; Software tool to identify predatory publications developed by SPPU; Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggested, etc.

 Publication Misconduct: (i) Group Discussions: Subject specific ethical issues, FFP, authorship; Conflicts of interest; Complaints and appeals: examples and fraud from India and abroad; (ii) Software Tools: Use of plagiarism software like Turnitin, Urkund and other open-source software tools.

 Databases and Research Metrics: (i) Databases: Indexing databases, Citation databases: Web of Science, Scopus, etc.; (ii) Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g index, i10 index, altmetrics.

**References**

1. Philosophy of Science by A. Bird (Routledge, London, 2006).

 2. A Short History of Ethics by A. Macintyre (Routledge, London,1967).

3. Ethics in Competitive Research: Do not get scooped; do not get plagiarized by P. Chaddah (2018); ISBN:978- 9387480865.

 4. On Being a Scientist: A Guide to Responsible Conduct in Research by National Academy of Sciences, National Academy of Engineering and Institute of Medicine (The National Academies Press, 3rd Edition, 2009).

5. What is ethics in research & why is it important? by D. B. Resnik (National Institute of Environmental Health Sciences, 1-10, 2011). Retrieved from https://www.niehs.nih.gov/researchlresources/bioethics/whatis/index.cfrn .

6. Predatory publishers are corrupting open access by J. Beall (Nature, 489, 179-179, 2012). https://doi.org/10.1038/489179a.

7. Ethics in Science Education, Research and Governance by Indian National Science Academy (INSA), 2019), ISBN:978-81-939482-l-7. http://www.insaindia.res.in/pdf!Ethics Book.pdf.

**Advanced Statistical Mechanics (PHYOC54)**

UNIT-I

 Langevin equation, Fluctuation-dissipation theorem, Wiener-Khintchine theorem, Nyquisttheorem and applications, Onsager reciprocal relations. (12)

UNIT-II

 Boltzmann transport equation. Fokker-Planck equation, Master equations.

 Thermal ratchets. (12)

UNIT - III

 Phase transitions: Principles and practices, Landau theory. (12)

UNIT - IV

 Fluctuations. Scaling hypothesis. Basic ideas of renormalization group. (12)

**Books and References**

1. R.E. Wilde and S. Singh, Statistical Physics, Fundamental and Modern Applications, John Wiley & Sons, 1998.

2. K. Huang, Statistical Mechanics, Wiley & Sons, 2000

3. L.D. Landau and E.M. Lifshiftz, Statistical Physics (Course of Theoretical Physics Vol. 5), Butterworth Heinemann, 1999.

4. C. Kittel, Elementary Statistical Physics, John Wiley & Sons, 1967.

5. C. Kittel and H. Kroemer, Thermal Physics, CBS Publishers and Distributors, 1987.

6. F. Reif, Fundamental of Statistical and Thermal Physics, McGraw Hill, 1998.

7. N. Goldenfeld, Lecture on Phase Transition and Renormalization Group, Levant Books, Kolkata, 2005.

8. C.W. Gardiner, Hand Book of Stochastic Method for Physics, Chemistry and Natural Sciences, Springer, 2004.

9. H. Risken and T. Franz, Fokker-Planck Equation: Methods of Solutions and Applications, Springer, 1996.

10. S. K. Ma, Modern Theory of Critical Phenomena, Benjamin, 1975.

**HIGH ENERGY PHYSICS (PHYOC55)**

Unit I: Gauge Symmetries

The Lagrangian and equations of motion; Noethers theorem; symmetries and conservation laws. U(1) gauge invariance and quantum electrodynamics (QED). SU(2) and SU(3) local gauge invariance. Non-abelian gauge invariance and quantum chromodynamics (QCD). (8)

Unit II: Standard Model

Massive gauge bosons; spontaneous symmetry breaking. Spontaneous breaking of a global gauge symmetry. The Higgs mechanism; spontaneous symmetry breaking of a local SU(2) gauge symmetry. The Weinberg-Salam model. Masses of gauge bosons; the Weinberg angle. Masses of fermions. Lagrangian of the Standard Model; Feynman rules. Basic ideas of the renormalization of the Standard Model. The renormalization group equations. (15)

Unit III: Weak Interactions

Muon and pion decay. Charged-current neutrino-electron scattering; neutrino-quark scattering. Neutral currents; neutral-current neutrino-quark scattering. The Cabbibo angle; weak mixing angles; CP noninvariance. CP violation: the neutral kaon system. (15)

Unit IV: Strong Interactions

Charge distributions of hadrons; form factors. Electron proton scattering; proton form factors; inelastic scattering as a virtual photon-proton total cross section. Partons; Bjorken scaling; quarks within the proton; gluons. Electron-positron annihilation into hadrons; three jet events; the Drell-Yanprocess. (10)

**Text Books:**

11. Relativistic Quantum Fields by J. D. Bjorken and S. D. Drell( McGraw-Hill, 1st Edition, 1965).

12. Quantum Field Theory by C. Itzykson and J.-B. Zuber (Dover Publications, 2006).

13. Quarks and Leptons: An Introductory Course in Modern Particle Physics by F. Halzen and A. D. Martin (Wiley, 1st Edition, 1984).

14. Introduction to Gauge Field Theories by M. Chaichianabd N. F. Nelipa (Springer, 1984).

15. Relativistic Quantum Mechanics by J. D. Bjorken and S. D. Drell (McGraw-Hill, 1st Edition, 1998).

**Reference Books:**

1. The Quantum Theory of Fields Volume 1: Foundations by S. Weinberg (Cambridge University Press, 1996).

2. The Quantum Theory of Fields Volume 2: Modern Applications by S. Weinberg (Cambridge University Press, 2005).

**LASER PHYSICS (PHYOC56)**

Unit I: Interaction of Radiation with Matter

 Quantum theory of interaction of radiation field with matter: Quantization of the electromagnetic field; the coherent states; transition rates; the phase operator. (6)

Unit II: Scattering of Radiation

 Scattering of photons by atomic electrons; Kramers-Heisenberg formula; Rayleigh scattering; Thompson scattering; the Raman eﬀect; radiation damping and resonance flourescence.(6)

Unit III: Laser Processes

 Dynamics of laser processes; switching systems; mechanical shutter; Electro-Optical shutters; Kerr eﬀect; Pockels eﬀect; shutters using satuarable dyes; peak power emitted during the pulse; Giant pulse dynamics; laser amplifiers; mode pulling; hole burning. (10)

Unit IV: Non-linear optics

 Non-linear optics; harmonic generation; second harmonic generation; phase matching; third harmonic generation; optical mixing; parametric generation of light; self-focussing of light. (6)

Unit V: Photon Processes

 Multiphoton processes: Multiquantum photoelectric eﬀect; theory of two photon processes; experiment in two-photon processes; three-photon processes; second harmonic generation; parametric generation of light; phase-conjugate optics. (8)

Unit VI: Spectroscopy

 Laser spectroscopy: Rayleigh and Raman scattering; stimulated Raman ef-fect; Hyper-Raman eﬀect; coherent anti-Stokes Raman scattering; spin-flip Raman laser; free-electron laser; photo-acoustic Raman spectroscopy; Brillouin scattering; saturation-absorption spectroscopy; Doppler-free two photon spectroscopy. (12)

**Text Books:**

1. Principles of Lasers by O. Sevelto (Springer, 4th Edition, 2009).

2. Lasers: Theory and Applications by K. Thyagarajan and A. Ghatak (MacMil-lan, 1999).

3. Raman Spectroscopy by D. A. Long (Mcgraw-Hill, June 1977).

4. The Raman Eﬀect: A Unified Treatment of the Theory of Raman Scat-tering by Molecules by D. A. Long (John Wiley, 2001).

5. Physics of Atoms and Molecules by B. H. Bransden and C. J. Joachain (Long-man Publishing, 1982).

**Reference Books:**

1. The Quantum Theory of Light by R. Louden (Oxford University Press, 3rd Edition, 2000).

2. Quantum Electronics by A. Yariv (John Wiley, 3ed Edition, 1989).

3. Laser Fundamentals by W. T. Silfvast (Cambridge University Press, 1996).

4. Introduction to Quantum Electronics by H. G. Unger (Pergamon Press, 1970).

**Nuclear Physics (PHYOC57)**

Unit-I: Alpha Decay and Cluster Decay: Quantum mechanical theory of alpha decay, Alpha particle energies and selection rules, Concept and theory of cluster decay. (8)

 Unit-II: Heavy Ion Induced Nuclear Reactions: Elastic and Inelastic scattering, Heavy ion potentials, Compound nucleus formation in heavy ion reactions, Fusion of heavy ions, Intermediate structure.

 High energy interactions: Deep inelastic scattering, Friction process, Collective modes of mass transfer, Heavy ion interactions at relativistic energies. (10)

Unit-III: Nuclear Detectors and Techniques: Track revelation techniques, Tract registration process, Geometry of tracks, Chemical etching, transmission electro microscope observation, Chemical etching, Tract counting and its applications, Nuclear particle identification (E-delta E Counter telescope time, Measurement of particle of light) energy, Background radiation, Sources of background radiation, Techniques of background reduction. (10)

Unit-IV: Statistical Analysis of Nuclear Data: Multichannel analyzer and its characteristics, Spectrum analysis. Characterization of nuclear data, Statistical models, Hauser Feshback formula &Breit Wigner Theory for more than 1 level.

 Error Analysis: The statistical error of radiation measurements, The standard error of counting rates, Methods of error reduction. (10)

Unit-V: Energy production and Thermonuclear reactions, Thermonuclear reactions on the earth and in stars, Fission as a source of energy. Tracer techniques and its applications. Application of radiations for food preservation, Chemical and biological effects of radiations. (10)

**Books and References:**

1. H.S. Hans, Nuclear Physics Experimental and Theoretical, New Age International (P) Ltd. Publisher, 2001.

2. G.F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, 2000.

3. S.A. Durrani& R. Ilic, Radon Measurements, by Etched Tract Detectors World Scientific Publishing Co. Pvt. Lt., 1997.

4. Nicholas Tsoulfanidis, Measurement and Detection of Radiation, Taylor & Francis, 1995.

 Concepts of Nuclear Physics, B.L. Cohen, Tata McGraw Hill Edition, 2007.

5. W. Greiner and R.K. Gupta (edited) Heavy elements and related phenomena, Vol. I & II, World Scientific, Singapore, 1999.

6. R.L. Fleischer, P.B. Price and R.M. Walber, Nuclear tracts in solids, Principles and applications, University of California Press, 1975.

**Atomic, Molecular and Optical Physics (PHYOC58)**

Unit - I : Introduction : Classification of collisions, Impact parameter for the collisions, Asymptotic- condition, Concept of low energies, intermediate energies and high energies, Atomic units. (12)

Unit – II : Inelastic ion-atom collisions – coupled channel models: The variational and the derivation of coupled channel equation (12)

Unit – III : The Formal theory of scattering- The S matrix, Transition probability for Direct collisions, rearrangement collisions, The Born series. The distorted wave formulation, Impulse approximation. (12)

Unit – IV : The molecular state expansion, coupled equations using the molecular co-ordinate system (s,R), The coupled equation in adiabatic representation , The sudden approximation. (12)

**Books and References :**

1. Physics of Atoms and Molecules by B.H.Bransden and C.J.Joachain. Pearson education (2006)

2. Introduction to the quantum theory of scattering by L.S.Rodberg and R.M.Thaler. Academic Press (1967)

3. Introduction to ion-atom collisions by M.R.C.McDowell and J.P.Coleman. North-Holland Publishing, Amsterdam (1970)

4. Charge exchange and theory of ion-atom collisions by B.H.Bransden and M.R.C.McDowell. Oxford University Press (1992)

5. M. Kimaura and N.F. Lane in Advances in atomic, molecular and optical physics, edited by D. Bates and B. Bederson (Academic Press, New York, 1990); vol. 26.

6. V. Sidis, in Advances in atomic, molecular and optical Physics, edited by D. Bates and B. Bederson (Academic Press, New York, 1990); vol. 26.