Introduction to nuclear reactions
A. Roy
Classification of nuclear reactions in time and energy scales, examples in different domains, reaction energy and Q-value, angular momenta, cross-sections, detailed balance, kinematics of reactions.

Elastic and inelastic scattering, the optical model
A. K. Jain

Break-up and transfer reactions
R. Chatterjee

1. Introduction
   • Qualitative features of nuclear reactions (direct reactions)
   • Lipmann-Schwinger equation, Two-potential formula, DWBA, rearrangement reactions
2. Transfer reactions
   • Angular momentum transfer and single particle structure information
   • Transition amplitude and cross sections
   • One and two-nucleon transfer reactions
3. Breakup reactions
   • Treating Coulomb, nuclear effects and their interference on the same footing
   • Calculation of reaction observables (inclusive and exclusive) and comparisons among different reaction theories
   • Extensions for deformed and three-body projectiles
4. Other Applications / Challenges (time permitting)
   • Nuclear Astrophysics: Charged particle and neutron capture rates
   • Scaling properties in exotic nuclei
   • Progress towards a unified theory of nuclear structure and reactions
Nuclear reaction studies using recoil separators

N. Madhavan

Kinematic focusing effect. Fusion and transfer reactions around barrier. Barrier distributions and angular momentum distributions using recoil separators / spectrometers.

Fusion at near and deep sub-barrier energies

S. Kailas

Fusion – sub-barrier, deep sub-barrier, incomplete fusion (ICF). How break up and transfer influence fusion. Experimental and theoretical aspects of complete and incomplete fusion. Fusion induced by strongly bound and weakly bound stable projectiles. Fusion by radioactive ions.

Nuclear fission

B. K. Nayak

Basics of heavy ion induced fission reaction, experimental techniques to measure fission fragment (FF) angular and mass distributions. Details on fission fragment angular and mass distribution with reference to compound nuclear and quasi-fission. Fusion-fission dynamics study through neutron and charged particle emission. Various fission models like SSPM, PEFM.

Fission studies using GPSC and NAND at IUAC

P. Sugathan

GPSC and NAND experimental set up, detectors, data collection and analysis. Measurements on mass and angular distribution of fission fragments and neutron multiplicity.

Statistical and dynamical models of CN decay

S. Pal

Lecture 1:
- Why a statistical approach to CN decay?
- Basic assumptions
- Transition state theory and decay widths of fission and evaporation channels
- Cascading effect in CN decay

Lecture 2:
- Monte-Carlo simulation of CN decay
- Flow chart of simulation of CN decay
- Introduction of dynamical model for fission
- Langevein equations
- Flow chart of evaporation coupled dynamical model calculation
Lecture 3: Introduction of Fokker-Planck equations  
Kramers’ fission width  
Statistical model calculation with Kramers’ width  
Inputs to statistical model calculations  
Open problems

### Detectors for nuclear reaction studies  
**A. Jhingan**


### Synthesis of man-made elements  
**S. Nath**

The periodic table of elements – natural and man-made elements, limits of existence of nuclei, synthesizing heavier nuclei by sequential capture of neutrons, spontaneous fission, role of shell correction, prediction of island of stability, experimental challenges and requirements, hot fusion reactions, cold fusion reactions, $^{48}$Ca-induced reactions, decay of super-heavy elements, naming of new elements, placement in the periodic table, current status of SHE research and future directions.

### Nuclear reactions for nuclear astrophysics  
**R. Shyam**

1. Lecture One:
   - *(i) Introduction*
     - Life cycle of a star, universal abundance curve.
     - Major challenges of nuclear astrophysics.
   - *(ii) Some Preliminaries*
     - Binding energy per nucleon vs. nuclear mass, Q-value of a reaction, cross sections, basic reaction mechanism involved in strong or electromagnetic reactions.
     - Energy source of a star, stellar temperature scale.

2. Lecture Two:
   - *(i) Stellar Nucleosynthesis*
     - p-p chain, Solar neutrino problem, evidence for neutrino mass, $^8$B neutrinos, CNO Cycle.
     - He-burning, triple alpha problem and synthesis of $^{12}$C, Saha equation of ionic equilibrium, Use in explaining the synthesis of $^{12}$C.
     - Heavy ion burning, s- and r- neutron process.
   - *(ii) Energy Scales and Reaction Rates*

3. Lecture Three:
   - Indirect Methods of Determining the Rates of Nuclear Reactions of Astrophysical Interest
(i) Reminder of Some Basic Nuclear Reaction Theories
Elastic and inelastic breakup reactions, spectator-participant and sequential mechanisms of breakup reactions.
(ii) Coulomb Dissociation Method as Applied to Radiative Fusion Reactions of Astrophysical Interest
Basic theory, applications to the existing experiments on radiative fusion reaction $p + ^7\text{Be} \rightarrow ^8\text{B} + \gamma$, application to $n + ^4\text{Li} \rightarrow ^8\text{Li} + \gamma$ reaction, application to $n + ^{30}\text{Mg} \rightarrow ^{31}\text{Mg} + \gamma$ reaction, and others.

4. Lecture Four:
Indirect Methods of Determining the Rates of Nuclear Reaction of Astrophysical Interest (Continued)
(i) Trojan-Horse Method
Basic theory, applications to the measurements performed in several laboratories.
(ii) Asymptotic normalization constant (ANC) method
Basic theory, extraction of ANC coefficient from the transfer reaction measurements. Conditions for applicability, Discussions of the experiment done at the IUAC.

Intermediate energy nuclear reactions
S. Bhattacharya

Lecture 1: Beyond complete fusion – pre-equilibrium emission, incomplete momentum transfer, theoretical models (exciton model, stochastic nucleon exchange model), signatures of ICF process (velocity of ICF composite, fission folding angle), transition to Fermi energy domain – experimental signatures.
Lecture 2: Transition to Fermi energy domain (contd.), global variables and physical observables – event characterization.

Relativistic nuclear collisions
R. Sahoo

1. Introduction to Relativistic Nuclear Collisions: Motivation, Methods: high temperature vs high baryon density, The QCD Phase Diagram, Deconfinement Transition, Evolution of the system after heavy-ion collisions.
3. Observables in Relativistic Nuclear Collisions: Transverse momenta, transverse mass, transverse energy, initial energy density (comparison with lattice QCD), rapidity width and Equation of State, invariant distributions and thermodynamics, Global Observables (Charged Particle and transverse energy Rapidity distributions).
5. Particle Production in proton-proton vs nucleus-nucleus collisions (time permitting).