MANGALORE UNIVERSITY
MSc Medical Physics

MPH 402: Nuclear and Radiation Physics

Teaching hours: Each Unit – 12 h

Objective:

To acquaint the students about the basics of nuclear and radiation physics required to understand, appreciate and apply in diagnosis and therapy using nuclear radiations and radioisotopes.

Outcomes:

- Students will be familiar with the basics of nuclear physics including nuclear models and nuclear forces required to understand their interaction processes and behaviour with matter.
- They will understand basics of alpha and beta decay useful in health application of radioisotopes and radiations.
- Students will learn about nuclear reactions which are of primary importance in understanding the production of radioisotopes for therapy and diagnosis.
- They will get familiar with different kinds of radiations and radioisotopes and their interaction with matter.
- They will also learn basics of electronics involved in radiation detection and counting systems.

Unit I: Basics of Nuclear Physics

General properties of the nucleus and nuclear decay: Constituents of nucleus and their properties. Mass of the nucleus - binding energy. Charge and charge distribution. Size - estimation and determination of the nuclear radius. Nuclear radius from mirror nuclei - spin statistics and parity. Magnetic moment of the nucleus.Quadrupole moment.
Nuclear decay - Alpha decay - quantum mechanical tunnelling - wave mechanical theory.

Beta decay - continuous beta ray spectrum - neutrino hypothesis. Fermi‘s theory of beta decay - Kurie plots and ft-values - selection rules.Detection of neutrino - non-conservation of parity in beta decay. Gamma decay - selection rules - multipolarity - Internal conversion (qualitative only).

Unit II: Nuclear Forces and Nuclear Models

Nuclear forces and nuclear models: Nature of nuclear force - short range, saturation, spin dependence and charge independence. Ground state of the deuteron using square well potential - relation between range and depth of the potential.Yukawa‘s theory of nuclear forces and explanation of anomalous magnetic moment of the nucleus.

Review of nuclear models - liquid drop model - semi empirical mass formula - stability of the nuclei against beta decay - mass parabola. Shell model (qualitative treatment).

Unit IV: Nuclear Reactions

Nuclear reactions - Cross section for a nuclear reaction. _Q' equation of a reaction in laboratory system - threshold energy for a reaction. Centre of mass system for nucleus-nucleus collision. Non-relativistic kinematics.Relation between angles and cross sections in lab and CM systems.

Reactor physics: fission chain reaction. Slowing down of neutrons - moderators.Conditions for controlled chain reactions in bare homogeneous thermal reactor.Critical size.Effect of reflectors.Brief introduction of nuclear fuel cycle.Breeder Reactors.

Unit IV: Interaction of Radiation with Matter

Interaction of radiation with matter: Interaction - stopping power - energy loss characteristics, particle range - energy loss in thin absorbers. Scaling laws.Interaction of fast electrons - specific energy loss.Electron range and transmission curves.

Interaction of gamma rays - interaction mechanisms - photoelectric absorption, Compton scattering and pair-production. Gamma ray attenuation - attenuation coefficients, absorber mass thickness, cross sections.

Interaction of neutrons - general properties - slow down interaction, fast neutron interaction, neutron cross sections. Radiation exposure and dose – dose equivalent.

Unit IV: Nuclear electronics

Preamplifier circuits, linear and pulse amplifier, pulse shaping, pulse stretching. Wilkinson type analog to digital converter. Pulse discriminators - coincidence and anticoincidence circuits - memories, single and multichannel analysers – on-line data processing - time to amplitude converter - charge sensitive amplifier. Basic principles of measurement techniques such as collimation, shielding, geometry and calibration.

Text Books:

1. Segre E, _Nuclei and Particles', II Edn. (Benjamin, 1977)
2. Knoll G F, Radiation Detection and Measurement', II Edn. (John Wiley, 1989)
3. Eisenbud M, _Environmental Radioactivity' (Academic Press, 1987)
4. Ghoshal S N, _Atomic and Nuclear Physics', Vol. I & II (S Chand & Company, 1994).

Reference Books:

1. Patel S B, _Nuclear Physics - An Introduction' (Wiley Eastern, 1991)
2. Krane K S, _Introductory Nuclear Physics' (John Wiley, 1988)
3. Roy R K and Nigam P P, _Nuclear Physics - Theory and Experiment' (Wiley Eastern Ltd., 1993)
4. Singru R M, _Experimental Nuclear Physics' (Wiley Eastern, 1972)
5. Zweifel P F, _Reactor Physics', International Student Edn. (McGraw Hill, 1973)

6. Kapoor S S and Ramamurthy V S, ‗Radiation Detectors‘ (Wiley Eastern, 1986)
7. Henry Semat& John R AlBright, ‗Introduction to Atomic and Nuclear Physics‘ V Edn. (Chapman & Hall, 1972)
8. Burcham W E, ‗Nuclear Physics‘, II Edn. (Longman, 1963)
9. Mann W B, Ayres R L and Garfinkel, ‗Radioactivity and its Measurements‘ (Pergamon Oxford, 1980)
10. Little field T A and Thorley N ‗Atomic and Nuclear Physics‘, II Edn. (Nostrand Co., 1988).
11. K.S.Krane, "Introductory Nuclear Physics", (John Wiley & Sons)

12. Practical Applications of Radioactivity and Nuclear Radiations, G.C.Lowental and P.L.Airey, Cambridge Universiyt Press, U.K., 2001.
13. F.M Khan : ―Physics of Radiation Therapy‖ Fourth Edition.
14. J.R Greening, Medical Physics, North Holland publishing Co, New York, 1981.
15. H.E.Jones, J.R.Cunnigham, ―The Physics of Radiology‖ Charles C.Thomas, NY, 1980.
16. W.J.Meredith and J.B.Massey ―Fundamental Physics of Radiology‖ John Wright and sons, UK, 1989.
17. W.R.Hendee, ―Medical Radiation Physics‖, Year Book – Medical Publishers Inc.
18. London, 1981.
19. E.J.Hall Radiobiology for Radiologists J.B.Lippincott Company, Philadelphia 1987.