



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 University 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.

