

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 15c: RADIATION AND ITS APPLICATIONS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Radiation and its Applications PHYSICS DSE – 15c	4	2	0	2	Class XII pass with Physics and Mathematics as main subjects	NIL

LEARNING OBJECTIVES

The Learning Objectives of this course are as follows.

- To focus on the applications of nuclear techniques and radiation protection.
- To not only enhance the skills towards the basic understanding of the radiation but also provide the knowledge about the protective measures against radiation exposure.
- To impart all the skills required by a radiation safety officer or any job dealing with radiation such as X-ray operators, jobs dealing with nuclear medicine: chemotherapists, operators of PET, MRI, CT scan, gamma camera etc.

LEARNING OUTCOMES

After studying this course, the student will be able to,

- Understand and use the applications of nuclear techniques and radiation protection to guard against nuclear radiation hazards.
- Understand and use the units of radiations and their safety limits, the devices to detect and measure radiation.
- Understand and use radiation safety management, biological effects of ionizing radiation, operational limits and basics of radiation hazards evaluation and control, radiation protection standards,
- Use the devices which apply radiations in medical sciences, such as X - ray, MRI, PET, CT-scan with the required safety measures.
- Understand and perform experiments like study the background radiation levels using Radiation detectors, Determination of gamma ray linear and mass absorption coefficient of a given material for radiation shielding application.
- Use graphical software to plot the simulations done through SRIM or similar software.

SYLLABUS OF PHYSICS DSE 15c

THEORY COMPONENT

Unit – I

(8 Hours)

Radiation and its interaction with matter: Basic ideas of different type of radiation electromagnetic (X-ray, gamma rays, cosmic rays etc.), nuclear radiation and their origin (stable and unstable isotopes), half life and mean life

Nuclear Radiation: Basic idea of alpha, beta, gamma and neutron radiation and their sources (sealed and unsealed sources). Kinematics of nuclear reactions, Q value

Interaction of charged particles (including alpha particles): Heavy charged particles (e.g.

accelerated ions) - Beth-Bloch formula, scaling laws, mass stopping power, range, straggling. Cherenkov radiation

Interaction of beta particles: Collision and Radiation loss (Bremsstrahlung).

Interaction of photons: Linear and Mass Attenuation Coefficients. Interaction of Neutrons: Collision, slowing down and Moderation.

Unit - II

(8 Hours)

Radiation Units, dosage and safety management:

Radiation Quantities and Units: Biological effects of ionizing radiation, Interaction of ionising and non-ionising radiation at the cellular level. Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, quality factor, radiation and tissue weighting factors, annual limit of intake (ALI) and derived air concentration (DAC).

Radiation safety management: Operational limits and basics of radiation hazards, its evaluation and control: radiation protection standards. Concept of ALARA Principle using Distance, time and shielding

Unit - III

(8 Hours)

Radiation detection and monitoring devices: Basic concepts and working principle of gas detectors, Scintillation Detectors, Solid State Detectors and Neutron Detectors, Types of Radiation Dosimeters: thermoluminescence, radiographic films, calorimetry, semiconductor diodes; Relation between detection and dosimetry, Interaction of ionising and non-ionising radiation at the cellular level.

Unit - IV

(6 Hours)

Application of radiation as a technique: Application in medical science (e.g., basic principles of X- rays, MRI, PET, CT scan, Projection Imaging Gamma Camera, Radiation therapy), Archaeology, Art, Crime detection, Mining and oil. Industrial Uses: Tracing, Gauging, Material Modification, Sterilization, Food preservation.

References:

Essential Readings:

- 1) Basic ideas and concepts in nuclear physics: An introductory approach, K. Heyde, 3rd edition, 1999, IOP Publication.
- 2) Nuclear Physics, S. N. Ghoshal, 1st edition, 2010, S. Chand Publication
- 3) Nuclear Physics: Principles and Applications, J. Lilley, 2006, Wiley Publication
- 4) Fundamental Physics of Radiology, W. J. Meredith and B. Massey, 1989, John Wright and Sons, UK
- 5) An introduction to radiation protection by A Martin and S A Harbison, John Willey & Sons, Inc. NewYork, 1981.
- 6) Radioactivity and Radiation, C. Grupen and M. Rodgers, 2016, Springer
- 7) Introduction to radiation protection, C. Grupen, 2010, Springer
- 8) An introduction to radiation protection, A. Martin, S. Harbison, K. Beach and P. Cole, H. Arnold, 2012.

Additional Readings:

- 1) Radiation detection and measurement, G. F. Knoll, 4th edition, 2010, Wiley Publications
- 2) Techniques for Nuclear and Particle Physics experiments, W. R. Leo, 1994, Springer
- 3) Thermoluminescence dosimetry, A. F. Mcknlly, Bristol, Adam Hilger (Medical Physics Hand book 5)

- 4) Medical Radiation Physics, W. R. Hendee, 1981, Year book Medical Publishers, Inc., London
- 5) Physics and Engineering of Radiation Detection, S. N. Ahmed, 2007, Academic Press Elsevier
- 6) Nuclear and Particle Physics, W. E. Burcham and M. Jobes, 1995, Harlow Longman Group
- 7) IAEA Publications: (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interim) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), RS-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007).

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least five experiments need to be performed from the following list.

- 1) Estimate the energy loss of different projectiles/ions (at least 3 projectiles between $Z_P = 1$ to 92, where Z_P is atomic number of projectile/ion) in water and carbon, using SRIM/TRIM etc. simulation software.
- 2) Simulation study (using SRIM/TRIM or any other software) of radiation depth in materials (Carbon, Silver, Gold, Lead) using H as projectile/ion.
- 3) Comparison of interaction of projectiles with $Z_P = 1$ to 92 (where Z_P is atomic number of projectile/ion) in a given medium (Mylar, Aluminium, cadmium, lead) using simulation software (SRIM etc).
- 4) SRIM/TRIM based experiments to study ion-matter interaction of heavy projectiles on heavy atoms. The range of investigations will be $Z_P = 6$ to 92 on $Z_A = 16$ to 92 (where Z_P and Z_A are atomic numbers of projectile and atoms respectively). Draw and infer appropriate Bragg Curves.
- 5) Calculation of absorption/transmission of X-rays, γ -rays through Mylar, Be, C, Al, Fe and $Z_A = 47$ to 92 (where Z_A is atomic number of atoms to be investigated as targets) using XCOM, NIST (<https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html>).
- 6) Study the background radiation in different places and identify the source material from gamma ray energy spectrum. (Data may be taken from the Department of Physics & Astrophysics; University of Delhi and gamma ray energies are available in the website <http://www.nndc.bnl.gov/nudat2/>).
- 7) Study the background radiation levels using Radiation meter
- 8) Study of characteristics of GM tube and determination of operating voltage and plateau length using background radiation as source (without commercial source).
- 9) Study of counting statistics using background radiation using GM counter.
- 10) Study of radiation in various materials (e.g. K_2SO_4 etc.). Investigation of possible radiation in different routine materials by operating GM counter at operating voltage.
- 11) Study of absorption of beta particles in Aluminium using GM counter.
- 12) Detection of α particles using reference source & determining its half life using spark counter.
- 13) Gamma spectrum of gas light mantle (Source of Thorium).
- 14) Demonstration of radiation detection equipment for dose, risk and crime scene management.

References for laboratory work:

- 1) Schaum's Outline of Modern Physics, 1999, McGraw-Hill
- 2) Schaum's Outline of College Physics, E. Hecht, 11th edition, 2009, McGraw Hill
- 3) Modern Physics, K Sivaprasath and R Murugesan, 2010, S. Chand Publication
- 4) AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities, 2011
- 5) AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources., 2007.