Department of Physics
M.Sc. 1st Semester (Session: 2024-2025)
Course title: Radiation and Health Physics
Course code: PHY-5105 **Credit hours:** 03

(a) Rational/Course Summary:

Radiation and Health Physics introduces students to the principles, applications, and safety considerations of ionizing radiation in medical, industrial, and research environments. The course begins with the fundamental interactions of electromagnetic and particulate radiation with matter, followed by detailed study of radiation dosimetry, dose measurement techniques, and dosimetric quantities. Students learn about biological effects of radiation on living systems, including stochastic and deterministic effects, radiation risk assessment, and radiation weighting concepts. The course covers a wide range of health physics instrumentation, gas-filled detectors, scintillation counters, semiconductor detectors, and various personnel dosimeters, emphasizing practical monitoring and measurement. International radiation protection standards, regulatory frameworks, and dose limits are discussed to ensure students understand the philosophy and implementation of radiation safety. Finally, the course examines external and internal radiation protection techniques, shielding methods, and radioactive waste management. By integrating theory, instrumentation, biological impact, and protection guidelines, this course prepares students for professional practice in medical physics, radiation safety, nuclear research, and regulatory sectors.

(b) Course Contents:

1. **Interaction:** Interaction of Ionizing and Electromagnetic Radiations with Matter, Beta Rays: Range-energy relationship, Mechanisms of energy loss; Alpha Rays: Range-energy relationship, Energy Transfer, Gamma Rays: Exponential absorption, interaction mechanisms, Neutrons: production classification. Interaction: Scattering, absorption, neutron activation.

2. **Radiation Dosimetry:** Film Badge; TLD (merit and demerits); Purpose of personnel dosimetry; Area monitoring; Portable radiation dose rate meter, Dose units (Absorbed dose, exposure); Exposure Measurement (Free air chamber, Air wall chamber); exposure dose relationship, Absorbed dose Measurement (Bragg-Gray principle, kerma); Source strength (Specific gamma ray emission, internally deposited radioisotopes, corpuscular radiation, effective half-life); Total dose (Dose commitment, gamma emitters, MIRD method, neutrons).

3. **Biological effects of Radiation:** Somatic and genetic effects; Stochastic and deterministic effects; Effective half-life of radioisotopes within biological being, Dose-Response Characteristics: Direct action, indirect action, Radiation effects: Acute effects, delayed effects; Risk estimates: BEIR III, Relative biological effectiveness (RBE) and quality factor (QF); Dose equivalent: Sievert (and the rem), high energy radiation.

4. **Health Physics Instrumentations:** Radiation detectors: Particle counting instruments, gas filled particle counters, ionization chamber counter, proportional counter, Geiger counter, quenching a Geiger counter, Resolving time: Measurement of resolving time, scintillation counters, nuclear spectroscopy, Cerenkov detector, semiconductor detector; Dose-Measuring Instruments: Pocket dosimeters, film badges, thermo-

luminescent dosimeter, Ion current chamber, neutron measurements, detection reactions, neutron counting with a proportional counter, long counter, proton recoil counter, neutron dosimetry.

5. **Radiation Protection Guides:** Organizations of Set Standards; Basic Radiation Safety Criteria: Effective dose equivalent, exposure of individuals in the general public, exposure of populations, medical exposure, allowable limit of intake (ALI), inhaled radioactivity, derived air concentrations (DAC), gastrointestinal tract, combined exposure; Basis for radiation Safety Regulations: Calculation of MPC in drinking water based on dose to critical organ, concentration in drinking water based on comparison with radium, airborne radioactivity, maximum permissible concentrations for non-occupational exposure.

6. **External Radiation Protection:** Basic Principles; Techniques of External Radiation Protection: Time, distance, shielding, X-ray shielding, beta ray shielding, neutron shielding.

7. **Internal Radiation Protection:** Internal radiation hazard; Principles of Control: Control of the source, confinement, environmental control; control of Man: Protective clothing, respiratory protection, surface contamination limits; Waste Management: High-level liquid wastes, intermediate and low-level liquid wastes.

(c) Course Learning Outcomes (CLOs):

After successful completion of the course, students will be able to-

CLO-1 : Understand the fundamental mechanisms of interaction of ionizing and electromagnetic radiations (α, β, γ, and neutrons) with matter, including energy loss processes, range–energy relationships, scattering, absorption, and neutron activation.

CLO -2 : Apply radiation dosimetry principles and measurement techniques to determine exposure, absorbed dose, kerma, dose equivalent, and committed dose using standard dosimeters, ionization chambers, and established methods such as the Bragg–Gray principle and MIRD formalism.

CLO -3 : Analyze the biological effects of radiation by distinguishing between stochastic and deterministic effects, somatic and genetic damage, dose–response relationships, and risk models, including RBE, quality factors, and BEIR recommendations.

CLO -4 : Evaluate radiation protection standards, regulatory limits, and safety criteria established by international and national organizations, including dose limits, ALI, DAC, MPC, and public and occupational exposure guidelines.

CLO -5 : Create internal radiation protection and waste management strategies by integrating source control, confinement methods, personal protective measures, contamination control, and radioactive waste handling for safe operation of radiation facilities.

(d) Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy:

CLOs	Teaching-Learning Strategy	Assessment Strategy
CLO-1	Lecturing and Discussion	Quiz
CLO-2	Discussion and Student Activities	Seminar Presentation and Summative Exam
CLO-3	Lecturing and Discussion	Mid-Term and Summative Exam
CLO-4	Lecturing and Discussion	Mid-Term and Summative Exam
CLO-5	Discussion and Student Activities	Assignment and Summative Exam

(e) Lecture Plan:

Lecture No.	Topics to be Discussed
1	Course introduction, overview of radiation and health physics, classification of ionizing and electromagnetic radiations
2	Interaction of charged particles with matter; stopping power and linear energy transfer (LET)
3	Beta rays: Range-energy relationship and mechanisms of energy loss
4	Alpha rays: Range-energy relationship, energy transfer, and stopping power
5	Gamma rays: Exponential attenuation and interaction mechanisms (photoelectric effect, Compton scattering, pair production)
6	**Quiz Test or Tutorial (mark: 5%)**
7	**Demonstration-I:** Radiation interaction experiments/simulation and attenuation measurements
8	Radiation dosimetry: Introduction, absorbed dose, exposure, kerma, dose units
9	Personnel dosimetry: Film badge, TLD (advantages and disadvantages), area monitoring, portable dose-rate meter
10	Exposure measurement: Free-air chamber, air-wall chamber, exposure-dose relationship
11	Absorbed dose measurement: Bragg-Gray cavity theory and kerma concepts
12	Source strength: Specific gamma-ray emission, internally deposited radionuclides, corpuscular radiation, effective half-life
13	Total dose: Dose commitment, gamma emitters, MIRD method, neutron dose estimation
14	**Mid-term Exam-I (mark: 10%)**

15	Biological effects of radiation: Somatic and genetic effects; stochastic and deterministic effects
16	Effective half-life of radionuclides in biological systems; dose-response characteristics
17	Direct and indirect actions of radiation; acute and delayed radiation effects
18	Risk estimates (BEIR III), Relative Biological Effectiveness (RBE), Quality Factor (QF), dose equivalent (Sv and rem)
19	Radiation detectors: Principles of radiation detection and particle counting instruments
20	Gas-filled detectors: Ionization chamber, proportional counter
21	Geiger-Müller counter, quenching mechanisms, resolving time and its measurement
22	Scintillation counters, Cerenkov detectors, semiconductor detectors, nuclear spectroscopy
23	Dose-measuring instruments: Pocket dosimeters, film badges, TLDs, ion current chambers
24	Neutron measurements: Detection reactions, proportional counter, long counter, proton recoil counter, neutron dosimetry
25	**Course Presentation-I (mark: 10%)**
26	**Demonstration-II:** Radiation detection instruments and neutron measurement techniques
27	**Mid-term Exam-II (mark: 10%)**
28	Radiation protection guides: International organizations and radiation safety standards
29	Basic radiation safety criteria: Effective dose equivalent, occupational and public exposure limits
30	Medical exposure, ALI, DAC, gastrointestinal tract model, combined exposure
31	Basis of radiation safety regulations: MPC in drinking water, airborne radioactivity, non-occupational exposure
32	External radiation protection: Basic principles and optimization (ALARA concept)
33	External radiation protection techniques: Time, distance, and shielding
34	Shielding design: X-ray, beta-ray, and neutron shielding
35	Internal radiation protection: Internal radiation hazards and control of the source

36	Confinement, environmental control, personal protection, respiratory protection, contamination control
37	Radioactive waste management: High-level, intermediate-level, and low-level radioactive wastes
38	**Course Presentation-II (mark: 10%)**
39	Course review, discussion of recent developments in radiation and health physics, question-answer session and final revision

(f) Evaluation Strategy:

(I) Before Final Assessment (mark: 40%):

(a) Mid-term Exam-I (mark: 10%)
(b) Mid-term Exam-II (mark: 10%)
(c) Quiz Test or Tutorial (mark: 5%)
(d) Course Presentations (mark: 10%)
(e) Class Attendance (mark: 5%)

(II) Final Exam (mark: 60%)

(g) Book Reference:

Introduction to Health Physics (Fourth Edition), The McGraw-Hill Companies, Inc.

- Herman Cember and Thomas E. Johnson