BABA FARID UNIVERSITY OF HEALTH SCIENCES

Annexure – C as per agenda item no. 8

i.e. Ordinances and Syllabus of M.Sc. Nuclear Medicine Technology according to Annual System of AGENDA

for the 29th meeting of the

ACADEMIC COUNCIL

to be held on 20.12.2019 at 11:00 am
in the Senate Hall
BFUHS, Faridkot

FARIDKOT-151 203

from Nuclear Medicine department.

Baba Farid University of Health Sciences

Ordinances & Syllabus

M.Sc. Nuclear Medicine Technology
(2 Years Degree Programme)

Faridkot -151203

Ordinances
M.Sc. Nuclear Medicine Technology

1. Duration of Course:

Duration of Master of Science in Nuclear Medicine Technology hall be of two years.

2. Eligibility for admission

a) This course shall be open to a candidate who have passed B.Sc. Medical/Non-medical Physics, Chemistry & Biology/Mathematics as one of the ancillary subject OR B.Sc. Nuclear Medicine/Radiation Sciences/ Biophysics/ B. Pharmacy as a regular student with 50% marks, from a recognized College/Institution/University.

OR

b) Any other examination recognized by the Board of Management of this University as an equivalent course / examination thereto, from time to time.

OR

c) B.SC, DMRIT will be also eligible for lateral entry into 2nd year of the M.Sc. NMT course.

3. Medium of Instructions

The medium of instruction during the course and examinations shall be English.

4. Examination Schedule:

4.1 The examination shall be held twice a year in the months of May/June and November/December or on such other dates as may be decided by the Board of Management on the recommendation of Faculty of Medical Sciences and Academic Council.

4.2 Normally, the University shall conduct not more than two examinations in a year, for any subject, with an interval of not less than four and not more than six months between the two examinations.

4.3 The last date by which examination forms and fee must reach the Controller of Examinations/Registrar shall be as follows : -

Examinations	without late fee	with late fee of Rs.200/-	with late fee of Rs.500/-	with late fee of Rs.1500/-
May/June	March 1	March 15	March 31	April 15
Nov./Dec.	Sept. 15	Sept. 30	Oct. 15	Oct. 31

Note: Vice-Chancellor may permit acceptance of examination form and fee ten days before the commencement of examination with a late fee of Rs.2000/-. The fee structure is revisable by the University from time to time.

5. First year M.Sc. Nuclear Medicine Technology

a) The First Year M.Sc. Nuclear Medicine Technology hall be open to a person who has been enrolled for one academic year preceding the examination in a Colleges/Institutions affiliated to this University.

b) submitted his/her name to the Controller of Examination/Registrar by the Head of the Research Centre/Institution/College with the following certificates:-

i) of having attended separately in theory and practical/clinical not less than 75% percent of the lectures delivered and practicals conducted in each of the subjects prescribed for the examination provided that deficiency in the number of lectures delivered and practicals conducted may be condoned by the Head of the Research Centre/Institution/College to the extent of 10% of the lectures delivered.

ii) of having secured at least 35% marks of the total marks fixed for internal assessment in each subject, separately, in order to be eligible to appear in all University examinations.

iii) of good moral character.

Note: 1) Internal Assessment shall be submitted to the University at least two weeks before the commencement of theory examinations or within one week from the issuance of Roll Numbers by the University. All the colleges shall adopt uniform criteria for Internal Assessment as follows:-

a) Attendance above 90% to be acknowledged with 10% extra weight-age for Internal Assessment.

b) At least two tests to be held in each year in addition to the pre-final (send up) examination. The Internal Assessment should be the average of all awards of these tests taken together.

c) Criteria for calculation of Internal Assessment

i)	House Examinations	- 80%
ii)	Attendance (above 90%)	- 10%
iii)	Subject assessment (candidate's conduct and extra curricular participation)	- 10%

d) Additional mandatory requirement for Internal Assessment to be observed by all colleges.

i) All test marks obtained by candidates will be displayed on Notice Boards of respective departments as and when they are awarded.

ii) All computations of Internal Assessment of the entire class made by the HOD of the department shall be displayed on the notice board of the department showing individual test marks, advantage of all tests, attendance advantage and subjective assessment and the total Internal Assessment thus derived for at least one week before sending the awards to the Principal's office.

iii) Professor Incharge/HOD preparing Internal Assessment shall certify that the detailed assessment of the entire class has been

displayed on the department Notice Board for at least one week prior to its being submitted for onward transmission to the University and that adequate opportunity has been given to all the students to file any objections and that the same have been addressed satisfactory.

iv) The Principal forwarding the Internal Assessment to the University shall countersign the above referred certificate of the HOD/Professor Incharge preparing the Internal Assessment.

e) The re-appear/fail students will be re-assessed every time for the purpose of Internal Assessment.

2) If a candidate fulfils the condition laid down in clause 5 above, he/ she may be allowed to take the examination.

3) Every candidate before appearing in Second Year Examination must have cleared House Examination securing at least 50 percent marks in both theory as well as practical separately.

c) The First Year M.Sc. Nuclear Medicine Technology Examination shall be held in May/June and the supplementary within six months of the Annual Examination.

d) The First Year M.Sc. Nuclear Medicine Technology hall be held in the by the University in the following subjects:-

Subject Code/ Paper	Subject	Theory			Practical				Grand Total
		Marks	Int. Assessment	Total	Marks	Int. Assessment	Viva	Total	
MSCNMT-01/ Paper - I	Basic concepts of Anatomy & Physiology	80	20	100	120	40	40	200	800
MSCMMT-02/ Paper – II	Applied Mathematics, Biostatistics and Computer Applications	80	20	100					
MSCNMT-03/ Paper – III	Radiation Physics, Radiation Detection and Measurements	80	20	100					
MSCNMT-04/ Paper – IV	Radiation Biology, Molecular and Cancer Biology	80	20	100					
MSCNMT-05/ Paper – V	Fundamentals of Electronics and Biomedical Instrumentation	80	20	100					
MSCNMT-06/ Paper – VI	Radioisotope Applications and Radiation Safety	80	20	100					

i) Each theory paper shall be of three hours duration.

ii) The minimum number of marks to pass the examination shall be 50% in theory including Internal Assessment in each subject and 50% in practical including the internal assessment and viva, separately.

iii) The candidate who will absent himself/herself from the examination will be deemed to have been failed in that subject.

iv) A candidate who passes in maximum in three subjects shall be exempted from appearing in these subjects at a subsequent examination. However, the candidate must pass the examination in a maximum of three (1+2) attempts +1 (mercy chance on the discretion of Vice-Chancellor) failing which, he/ she will not be allowed to continue his studies.

v) A candidate, who fails in three subjects maximum in his/her 1st attempt, shall be permitted to attend classes in Second Year M.Sc. Nuclear Medicine Technology. However, he/she will be allowed to appear in Second Year M.Sc. Nuclear Medicine Technology examination only after passing all the subjects of First Year M.Sc. Nuclear Medicine Technology.

6. Second Year M.Sc. Nuclear Medicine Technology

The Second Year M.Sc. Nuclear Medicine Technology hall be open to a person

a) who has been enrolled for two academic year preceding the examination in a Colleges/Institutions affiliated to this University.

OR

has admitted in 2nd year M.Sc. NMT course after passing B.Sc, DMRIT through lateral entry.

b) submitted his/her name to the Controller of Examination/Registrar by the Head of the Research Centre/Institution/College with the following certificates:-

i) of having attended separately in theory and practical/clinical not less than 75% percent of the lectures delivered and practicals conducted in each of the subjects prescribed for the examination provided that deficiency in the number of lectures delivered and practicals conducted may be condoned by the Head of the Research Centre/Institution/College to the extent of 10% of the lectures delivered.'

ii) of having secured at least 35% marks of the total marks fixed for internal assessment in each subject, separately, in order to be eligible to appear in all University examinations.

iii) of good moral character.

iv) Must have submitted Dissertation/Project Work .

Note: 1) Internal Assessment shall be submitted to the University at least two weeks before the commencement of theory examinations or within one week from the issuance of Roll Numbers by the University. All the colleges shall adopt uniform criteria for Internal Assessment as follows:-

a) Attendance above 90% to be acknowledged with 10% extra weight-age for Internal Assessment.

b) At least two tests to be held in each year in addition to the pre-final (send up) examination. The Internal Assessment should be the average of all awards of these tests taken together.

c) **Criteria for calculation of Internal Assessment**

i)	House Examinations	- 80%
ii)	Attendance (above 90%)	- 10%
iii)	Subject assessment (candidate's conduct and extra curricular participation)	- 10%

d) Additional mandatory requirement for Internal Assessment to be observed by all colleges.

i) All test marks obtained by candidates will be displayed on Notice Boards of respective departments as and when they are awarded.

ii) All computations of Internal Assessment of the entire class made by the HOD of the department shall be displayed on the notice board of the department showing individual test marks, advantage of all tests, attendance advantage and subjective assessment and the total Internal Assessment thus derived for at least one week before sending the awards to the Principal's office.

iii) Professor Incharge/HOD preparing Internal Assessment shall certify that the detailed assessment of the entire class has been displayed on the department Notice Board for at least one week prior to its being submitted for onward transmission to the University and that adequate opportunity has been given to all the students to file any objections and that the same have been addressed satisfactory.

iv) The Principal forwarding the Internal Assessment to the University shall countersign the above referred certificate of the HOD/Professor Incharge preparing the Internal Assessment.

e) The re-appear/fail students will be re-assessed every time for the purpose of Internal Assessment.

2) If a candidate fulfils the condition laid down in clause 6 above, he/ she may be allowed to take the examination.

3) Every candidate before appearing in Second Year Examination must have cleared House Examination securing at least 50 percent marks in both theory as well as practical separately.

c) The Second Year M.Sc. Nuclear Medicine Technology Examination shall be held in May/June and the supplementary within six months of the Annual Examination.

d) The Second Year M.Sc. Nuclear Medicine Technology hall be held in the by the University in the following subjects:-

Subject Code/ Paper	**Subject**	**Theory**			**Practical**				Grand Total
		Marks	Int. Assessment	Total	Marks	Int. Assessment	Viva	Total	
MSCNMT-07/ Paper – VII	Nuclear Medicine imaging and Counting Instrumentation	80	20	100	120	40	40	200	600
MSCNMT-08/ Paper – VIII	Principles and Practical of Radiological Protection, Radiation Dosimetry, Radiobiology and Hospital Practice	80	20	100					
MSCNMT-9/ Paper – IX	Principles and Practice of Radio pharmacy and Radionuclide Generators, SPECT and PET Radiopharmceuticals	80	20	100					
MSCNMT-10/ Paper – X	Nuclear Medicine Imaging and In-vivo Counting PET Imaging Cyclotron and Allied Instrumentation	80	20	100					

Subject Code/Paper	**Subject**	**Marks**			
		Marks in Dissertation/Project Work	**Internal Assessment/ Journal Club**	**Marks for Viva-voice**	**Total**
MSCMP-11/ Paper - XII	Dissertation/Project Work/ Viva	120	40	40	200

i) Each theory paper shall be of three hours duration.

ii) The minimum number of marks to pass the examination shall be 50% in theory including Internal Assessment in each subject and 50% in practical including the internal assessment and viva, separately.

iii) The candidate who will absent himself/herself from the examination will be deemed to have been failed in that subject.

iv) A candidate who passes in one or more subjects shall be exempted from appearing in these subjects at a subsequent examination, but the candidate must pass the examination in a maximum of three (1+2) attempts +1 (mercy chance on the discretion of Vice-Chancellor), failing which he/ she have to appear in the full subjects.

7. Dissertation/Project Work

i) Every candidate shall submit a Dissertation/Project Work plan to the University within one month from the date of declaration of First Year M.Sc. Nuclear Medicine Technology examination.

ii) Every candidate shall carry out work on an approved research project under the guidance of a recognized PG Teacher, the results of which shall be written up and submitted in the form of a Dissertation/Project Work by the candidate.

iii) Dissertation/Project Work shall be submitted to the University through Head of the Research Centre/College/Institution two months before completion of second year.

iv) The Vice-Chancellor may allow a candidate to submit the Dissertation/Project Work within one month after the date fixed for the purpose with the prescribed late fee.

v) The Dissertation/Project Work shall embody the results of the candidate's own research and/or experience and shall contain precise reference to the publications quoted, and must attain a good standard and shall be satisfactory in literary presentation and in other respects and should end with a summary embodying conclusions arrived at by the candidate. The Dissertation/Project Work shall be typewritten on one side of the paper (size 11" x 8 ½") with margins of 1½" on each side, bound, indicating on the outside cover its title and the name of the candidate.

vi) The Dissertation/Project Work shall be examined by a minimum of two examiners, one internal and one external examiner, during the Practical/Viva examination. One copy of Dissertation/Project Work will be handed over the external examiner before the Practical/Viva examination.

vii) The candidates who have submitted the Dissertation/Project Work in the University will be allowed to appear in the Second Year M.Sc. Nuclear Medicine Technology examination. However, the result shall be declared only on receipt of result of Dissertation/Project Work /Viva, from both the examiners.

viii) The internal examiner shall send only report to the University after evaluation of Dissertation/Project Work and the evaluated copy will be deposited in the college library for reference of the students.

8) Maintenance of Log Book

a) Every Post Graduate candidate shall maintain a record of skills (Log Book) he / she has acquired during the two years training period, certified by the various Heads of Department, where he / she undergoes training.

b) The candidate is also required to participate in the teaching and training programme for the under-graduate students.

c) In addition, the Head of the Department shall involve their Post-graduate students in Seminars, Journal Group Discussions and participation in Conferences.

d) The Head of the Department shall scrutinize the Log Book once in every three months.

9) Submission of Practical Record Books

At the time of Practical Examination, each candidate shall submit to the Examiners his / her Practical Record Books duly certified by the Head of the Department as a bonafide record of the work done by the candidate. The concerned Head of the Department shall evaluate the Practical Record (Internal Assessment) and the Practical Record shall be presented to the Examiner.

10) Number of Examinations

The examination shall be conducted twice a year in May/June and November/December or on such dates as determined by the University from time to time.

11) Grace Marks:

There shall be no provision for grace marks.

12. Board of Examiners

a) The examination shall be conducted by a Board of two examiners on the recommendations of the faculty of Medical Sciences.
b) All the PG Examiners should be recognized PG Teachers holding recognized PG qualifications in the subject.
c) Out of the two examiners one shall be external examiner

13. Paper setting and moderation of Question Papers:

The University may get each paper set from External Examiner only. The moderation of question papers may be got done under the directions of the Vice-Chancellor, if necessary.

14. Evaluation of Answer Books:

The answer books shall be got evaluated by putting fictitious roll numbers thereon or spot evaluation (table marking) or any other method under the directions of the Vice-Chancellor.

15. Declaration of Result and minimum pass marks:

A successful candidate on the basis of theory and practical marks taken together shall be classified as under: -

Second Class : A candidate obtaining 50% or more marks but less than 60% marks
First Class : A candidate obtaining 60% or more marks
First Class with Distinction: A candidate obtaining 80% or more marks

14. Award of Degree

Each successful candidate shall be awarded a degree of M.Sc. Nuclear Medicine Technology.

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SYLLABUS

M.Sc. Nuclear Medicine Technology

Instructions to Paper Setter

Note: 1) The question paper covering the entire course shall be divided into two sections. Each section to be attempted in a separate answer book and to be evaluated by separate examiners.

2) In each section there shall be 8 questions of 5 marks each and total weight-age being 40 marks

Section A **(Max. marks 40)**

Section B **(Max. marks 40)**

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Syllabus M.Sc. Nuclear Medicine Technology

FIRST YEAR

(53 Lectures)

Paper I- BASIC CONCEPTS OF ANATOMY AND PHYSIOLOGY

MICROSCOPIC ANATOMY (8 Lectures)

Basic tissue: Epithelial tissue-electron microscopic structure and various structural modifications.
Connective tissue: Blood and its formed elements, loose connective tissue, extracellular components, fixed cellular elements.
Muscle: Structural and molecular organization of muscle and mechanism of muscle contraction.
Nervous tissue: Neurons, neuroglial cells and nerve fibre. Mechanism of myelination and synapse

GROSS ANATOMY (18 lectures)

Anatomy and Imaging: Anatomical planes, diagnostic imaging techniques.
Back: Component parts (bones, muscles, vertebral canal, spinal nerves, dermatomes), regional anatomy (vertebrae, joints, ligaments, musculature), Back surface anatomy.
Thorax: Component parts (thoracic wall, thoracic aperture, diaphragm, mediastinum, pleural cavities, thorax surface anatomy.
Head and Neck: Component parts (skull, cervical vertebrae, hyoid bone, soft palate and muscles in the head and neck.
Abdomen: Component parts (wall, abdominal cavity, inferior thoracic aperture, diaphragm, pelvic inlet, surface anatomy, defining surface projection, Liver, kidney and spleen position, gallbladder, pancreas.
Pelvis: component parts (Pelvic inlet, pelvic walls, pelvic outlet, pelvic floor, pelvic cavity and perineum).
Lower and Upper limb: Component parts (bones and joints, muscles)

HUMAN PHYSIOLOGY (20 lectures)

Digestive system: Brief study of different digestive juices, their functions, digestion and absorption.
Urinary systems: Physiology of urine formation, collection and excretion, water and electrolyte balance.
Reproductive system: oogenesis and ovulation in females, spermatogenesis in males. Hormonal regulation in sperm formation and ovum formation.
Thyroid: Thyroid hormone production, storage and secretion, hormonal control.
Heart: The heart as a pump, cardiac cycle, cardiac contractility, rhythmic excitation, normal ECG, methods of recording ECG, vectorial analysis of ECG, cardiac arrhythmias.
Respiratory system: General physiological functions of respiratory system.
Endocrine system: Brief description of endocrine organs, their hormones, functions of the hormones, diseases produced by excess or deficiency of the hormones.
Nervous System: Structure, function and organization of Nervous system, signal transmission at synapses, spinal and cranial nerves.

INTRODUCTORY CYTOLOGY AND BIOCHEMISTRY (7 Lectures)

Cell: Cell wall and cell membrane, Structure and functions of Endoplasmic reticulum (ER), mitochondria, golgi complex, nucleus, lysosomes.

Brief introduction of structure and function of carbohydrates, proteins /enzymes, nucleic acids, lipids. Cell signaling, glycolytic and TCA cycles.

Books

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

1. Text Book of Medical Physiology, 11th ed. (Elsevier). Guyton and Hall
2. Principles of Anatomy and Physiology, 11th ed. Tortora and Derrickson (Wiley).
3. Text Book of Human Histology with Colour Atlas, 4th ed. (Jaypee). Inderbir Singh
4. Biochemistry, 4th ed. (WH freeman and company). Lubert Stryer
5. Cell and Molecular Biology, 8th ed. (BI Publication) De Robertis
6. Gray's Anatomy for students (Elsevier) R.L. Drake, Vogl & Mitchell :

FIRST YEAR -

(35 Lectures)

Paper II- APPLIED MATHEMATICS, BIOSTATISTICS AND COMPUTER APPLICATIONS

Numerical Methods: (8 Lectures)
Why numerical methods, accuracy and errors on calculations – round –off error, evaluation of formulae. Iteration for Solving x=g(x), initial approximation and convergence criteria, Newton Raphson method.

Probability, statistics and errors (15 Lectures)
Probability – addition and multiplication laws of probability, conditional probability, population, variates, collection, tabulation and graphical representation of data.

Basic idea of statistical distributions, frequency distributions, averages or measures of central tendency, arithmetic mean, properties of arithmetic mean, media, node, geometric mean, harmonic mean, dispersion, standard deviation, root mean square deviation, standard error and variance, moments, skewness and kurtosis.

Application to radiation detection-uncertainty calculation, error propagation, time distribution between background and sample, minimum detectable limit

Binomial distribution, Poisson distribution, Gaussian distribution, exponential distribution-additive property of normal variates, confidence limits, bivariate distribution, correlation and regression, chi-square distribution, t-distribution, F-distribution.

Counting and medical statistics (7 Lectures)
Statistics of nuclear counting-application of Poisson statistic- goodness of fit tests-Lexie's divergence coefficients, Pearson's chi-square test and its extension, random fluctuations, evaluation of equipment performance –signal to noise ratio, selection of operating voltage, preset of rate meters and recorders, efficiency and sensitivity of radiation detectors, statistical aspects of gamma ray and beta ray counting, special consideration in gas counting and counting with proportional counters, statistical accuracy in double isotope technique.
Sampling and sampling distributions- confidence intervals. Clinical study designs and clinical trials. HypoDissertation/Project Work testing and errors. Regression analysis.

Computational Tools & Techniques: (5 Lectures)
Computational packages: Overview of programming in C++, MATLAB/Mathematica and STATISTICA in data analysis and graphics.

Books

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

1. Numerical Methods for Engineers and Scientists, 2nd ed. (Marcel Dekker). Hoffman
2. Numerical Methods for Engineers and Scientists – A Student's Course Book (Wiley). A.C. Bajpai, I.M. Calcus & J.
   Introductory Methods of Numerical Analysis (Prentice Hall of India).S.S. Sastry
3. Introduction to Mathematical Physics (Wiley). Michael T vaughn
4. Elementary Statistics with Applications in Medicine and the Biological Sciences (Dover Publications). F.E. Croxton
5. Statistical methods of Medical & Biology Students (Allen & Unwin). G. Dahlberg
6. Ordinary Diff. Equation (Dover Publications). Morris Tenenbaum & Harry Pollard
7. C++ How to Program (Prentice Hall of India) Deitel & Deitel
8. Let us C (BPB, 2009) Y. Kanetkar

FIRST YEAR

(61 Lectures)

Paper III- Radiation Physics, Radiation Detection and Measurements

Radiation Physics (12 Lectures)

Radioactivity and decay laws: Types of radiation *(a,*β, γ, n, X-ray), decay modes, probability and decay constant, physical half life, mean life. Natural radioactivity& decay series, secular equilibrium, artificial radioactivity, beta particle spectrum, internal conversion, general aspects of gamma decay, gamma energy decay, Nuclear isomerism, neutron classification, neutron sources, neutron activation, nuclear fission, fission products, fissile materials, diffusion and slowing down of neutrons, various types of reactors - fusion and thermo nuclear reactions.

Radiation generators (6 Lectures)

X-ray Generators : Discovery- Production – Properties of X rays- Characteristic and continuous spectra- Design of hot cathode X-ray tube- Basic requirements of medical diagnostic, therputic and industrial radiographic tubes.

Particle accelerators for industrial, medical and research applications – The resonant transformer – cascade generator, Vande Graff Generator, pelletron, cyclotron, betatron, synchro–cyclotron.

Interactions of x and γ rays with matter: (5 lectures)

Scattering vs absorption: coherent scattering, photoelectric effect, Compton effect, pair production, annihilation radiation, photonuclear disintegration. Total and true absorption coefficients, attenuation of photon beams: attenuation, energy transfer, and energy absorption, exponential attenuation equation, attenuation coefficients, half-value layer, beam geometry.

Interactions of particulate radiation: Directly and indirectly ionizing particles, Elastic and inelastic collisions with orbital electrons and the nucleus, linear energy transfer, specific ionization, mass stopping power, range.

Interaction of charged particle with matter: (4 lectures)

Absorption process, scattering ionization and excitation, Bethe's equation, radiation energy loss (bremstrahlung), range of beta particles, backscatter and self absorption, Cerenkov radiation. Interaction of alpha particles, heavy nuclei and fission fragments with matter: Energy loss by collision, range-energy relation and Bragg curve, specific ionization, stopping power.

Interaction of neutrons with matter: (3 lectures)

Neutron capture, elastic scattering, energy transfer and logarithmic energy decrement, inelastic scattering, dependence on E and Z, (n, p), (n, x), (n, y) and other reactions, neutron activation.

Radiation Units (3 Lectures)

Units of radioactivity: Becquerel, Curie, specific activity, carrier free activity, Quantities and units: Dose, Roentgen unit of exposure, radiation sensitivity of biological materials, radiation absorbed dose (RAD, Gray), radiation weighting factor , Relative biological effectiveness (RBE), Quality factors, Roentgen Equivalent man (REM), Sievert , equivalent dose , effective dose, collective equivalent dose, total effective dose equivalent.

Gas filled detectors (4 Lectures)

Theory of ionization chamber, design consideration in an ionization chamber, operating voltage, theory and construction of condenser type of chambers and thimble chambers; gas multiplication, Proportional counters- design and characteristics. Geiger-Mueller counters – design consideration, dead time and recovery time, operation.

Scintillation detectors-Organic and Inorganic scintillation detectors (4 Lectures)
Scintillation detector principles- light collection and mounting, scintillation characteristics- light output, decay time, photo peaks, Compton valley, edge and plateau, backscatter peak, iodine escape peak, annihilation peak. Liquid scintillation counters: composition of liquid scintillator (scintillation cocktail): primary solute, secondary, solute and organic solvent (toluene, 1, 4 dioxane, anthracene) and solublzing agents for tissues, coincidence circuits and display. Quenching and quench correction methods: Internal standard method, external standard method and channel ratio.

General systems for operation and detection (8 lectures)
Neutron detectors: Basic principles and applications.
Well counter – Geometry factor, dual radionuclide counting.
Radiation calorimetry, photographic dosimetery. Chemical dosimetry: salient feature of chemical dosimeters. Spectrophotometry: Beer-Lambart's Law, definition of transmittance and absorbance (optical density), molar absorption and coefficient, Fricke dosimeter, FBX dosimeter, ceric, sulphate dosimeter, Low dose level dosimeters (aqueous benzoic acid, terephthalic acid, aqueous trimesic acid); High dose level dosimeters (red perspex HX, polyvinyl chloride, radio chromic dye and cellulose triacetate films).

Thermo luminescent Dosimeters & Autoradiography (5 Lectures)
Physics of TLD, characteristics TLD phosphors, glow curves, dose and energy response, sensitivity and application in-dosimetry and personnel monitoring devices.
Use of photographic emulsions stripping film technique, dipping method, grain density counting and track counting, X-ray films, intensifying screens, fluoroscopy.

Semiconductor detectors (2 Lectures)
Semiconductors junction and surface barrier detectors, high purity germanium detectors, their response and, characteristics.

Instruments for counting, gamma ray spectrometry (3 lectures)
PM tubes, preamplifiers, amplifiers, pulse height analyzers, coincidence & anti coincidence circuits, SCA, MCA, scalers and timers, high voltage supply, gamma ray spectrometry.

Whole body counting studies (2 Lectures)
Whole body counting: principles of whole body counting, design of whole body counting system, stationary systems, single and multiple crystal systems, chair geometry, moving systems, calibration of whole body system, clinical and other applications of whole body counters.

Books

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

1. Atomic Nucleus (McGraw Hill) R.D. Evans
2. Nuclear Physics (Narosa Pbl. House) I. Kaplan
3. Nuclear Radiation Physics (Prentice Hall) R.E. Lapp
4. Radiations from Radioactive Atoms (Govt. Print. Off.). L. Slack & K. Way
5. Radiation Physics in Radiology (Springer). R. Oliver
6. Field and Wave Electromagnetics (Addison-Wesley) D.K. Cheng
7. Radiation Detectors and Instrumentation (Wiley). Glenn F. Knoll
8. Techniques for Nuclear and Particle Physics experiments (Narosa). W.R. Leo
9. The Physics of Radiation Therapy (Lippincott Williams and Wilkins). F.M. Khan
10. Medical Imaging Physics (Wiley-Liss) W.R.Hendee & E.R.Ritenour

FIRST YEAR

(52 Lectures)

Paper IV- Radiation Biology, Molecular and Cancer Biology

Radiation Chemistry (3 Lectures)

Radiation Chemistry: direct and indirect effects of radiations, radiation chemical yields and G-values, formation of free radicals, radiolysis of water, radiation effects on simple chemical systems, interactions of free radicals with several solutes. Direct versus indirect effects in aqueous solutions. Reactions in aqueous, organic and inorganic solutions.

Radiation Biology (8 Lectures)

Radiation effects on Cell: membrane, energy metabolism, synthetic processes, chromosomes, chromosomal type aberrations, chromatid type aberrations, sub chromatid aberrations, relation between aberration structure and the mitotic and meiotic cycles. Radiation effects on cell division.

Radiation Molecular Biology: radiation effects on proteins, nucleic acids, carbohydrates, lipids, polymerases, transferases, isomerases and anti-oxidative enzymes.

Radiation effects on microorganisms and independent cell systems: target Theory, multitarget theory, target size, multihit theory, multitarget multihit theory.

Differential cell sensitivity: Criteria of sensitivity, factors affecting sensitivity, average interphase chromosomal volume, ploidy, nuclear factors, cytoplasmic factors, categories of mammalian cell sensitivity, specific classifications of mammalian cell sensitivity.

Radiation Effects on Major Organ Systems (6 Lectures)

Radiation effects on major organ systems: Hematopoietic system (Spleen, bone marrow, Lymphoid tissue, thymus) and Blood, vascular system, digestive system, respiratory system, urinary system, nervous system, reproductive system, endocrine system and immune system.

Modification of radiation injury (3 lectures)

Physical modifications of radiation injury, relative biological effectiveness, linear energy transfer, dose rate effect, chronic irradiation, biological factors influencing radiation response, age, diet, genetic constitution, oxygen concentration, temperature etc.

Acute radiation effects: Lethality, acute radiation syndrome in mammals, effects of prenatal development, radiation effects on regeneration.

Radionuclides in biology (15 lectures)

^{51}**Cr** labeling with red blood cells: applications in blood volume measurement, spleen uptake, red cell survival studies, red cell volume, proteins turn over.

^{59}**Fe absorption studies**, ^{59}Fe turn over studies, plasma iron clearance

^{58}**Co**/^{57}**Co**: Applications in schelling's test of vitamin B12 absorption, double tracer technique and whole body counting

^{60}**Co**: in cancer treatment, gamma knife

^{32}**P** applications in polycythemia vera and leukemia

^{14}C applications in urea breathe test, whole body counting, ^{14}C Glycoholic breath test, palmitic acid, Radio-respirometry, in vitro uptake studies using ^{14}C glusoce, ^{14}C amino acids and ^{3}H thymidine

^{45}**Ca**, ^{65}**Zn** and ^{3}**H** metabolic studies and other biomedical applications.

BIOLOGY OF CANCER (7 Lectures)

Classification, nomenclature and definition of neoplasms. Transformed cells and cell lines, cancer cells differentiation, alterations in cancer cell behavior, diminished contact inhibition and defects in cell to cell metastasis.

Cancer Invasion and Metastasis- Stages of metastasis (Invasion, local extention, discontinuous extention), transport of cancer cells to distant sites

MOLECULAR BIOLOGY and IMMUNOLOGY (10 Lectures)
DNA structure, Replication and Repair, RNA synDissertation/Project Work and Translation

Stem cells: Types of stem cells, embryonic and adult stem cells, haemopoetic stem cells, stem cells based therapies.

Types of immunity, mechanisms and measurement of immunity, antigens, antibodies, structure of Ab's, classification of antibodies, antigen-antibody interaction, and monoclonal antibodies. Structure and function of immune system, Immune response – humoral and cell-mediated immune response – primary and secondary responses.

FIRST YEAR

(29 Lectures)
Paper V- FUNDAMENTALS OF ELECTRONICS AND BIOMEDICAL INSTRUMENTATION

Semiconductor devices (8 Lecturers)
Intrinsic and extrinsic semiconductors, n-type and p-type semiconductors ,pn-junction properties forward and reversed bias, Zener diode, photo diode,PNP and NPN junction transistors, transistor current components, CB, CE and CC configurations, field effect transistor (FET), metal oxide filed effect transistor (MOFET). Simple ideas on operational amplifier, OPAMP, their characteristics and applications.

Digital Circuit System (4 Lectures)
Boolean algebra and logic gates: OR, AND, NOT, NOR, NAND and EXOR gates and their truth table flip-flops, shift registers, counters, decoders and encoders, analog to digital converter and digital to analog converters. Microprocessors and associated peripherals, power supplies-regulated power supplies using IC'S, AC-DC converter and RF power supplies, switching mode power supplies, AC regulators.

Radiography (5 Lectures)
High–voltage radiography, low voltage radiography, contrast media, radiographic grids, magnification radiography, digital radiography.
Single crystal scintillation camera, scintillation camera operation, multiple-crystal scintillation camera, tomography, computed tomography, reconstruction algorithm, scan motions, SPECT & PET.

Nuclear Magnetic Resonance and MRI (8 Lectures)
Angular momentum of the nucleus, Magnetism and the Magnetic Dipole, NMR parameters, Magnetization Vector, RF Field, the rotating coordinate system, Free induction decay, T1 and T2 relaxation, Mechanisms for relaxation, spin-Echo Techniques, Use of Fourier Transforms. Instrumentation -NMR System. Magnetic resonance as probe of the body-MRI, Gradient magnetic fields, Slice Selection, Phase Encoding, Frequency Encoding; Safety Considerations, Recent Developments, Functional MRI.

Biomedical Ultrasound & Medical Laser (4 Lectures)
Ultra sound generators, properties of ultrasound- waves and its propagation in biological tissues, pulse echo techniques, Doppler principle, ultrasound motion senses, dynamics of blood flow, physiological effects of ultrasound in therapy. Adverse effects of ultrasound waves.
Introduction to laser, principle of operation of laser, laser tissue interaction, different types of LASER. Attenuation of LASER in medicine, adverse effects of LASER

Books:

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

1. Semiconductor Devices: Physics and Technology (Wiley). S.M. Sze
2. Integrated Electronics (McGrew Hill). Millman and Halkias
3. OPAMPS and Linear Integrated Circuits (Pearson Education). Ramakant A. Gayakwad
4. Electronic Principles (McGrew Hill). A.P. Malvino
5. Principles of Applied Biomedical Instrumentation (Wiley). L.A. Geddes & L.E. Baker
6. Medical Imaging Physics (Wiley-Liss) W.R.Hendee & E.R.Ritenour

FIRST YEAR

(35 Lectures)
Paper VI- RADIOISOTOPE APPLICATIONS AND RADIATION SAFETY

BIO-MEDICAL APPLICATIONS OF RADIONUCLIDES (17 Lectures)

Thyroid radioactive uptake measurements: Tracer dose, use of carrier, standard and phantom, shielding and collimation, factors affecting thyroidal radioactive iodine uptake, PBI-131, thyroid stimulation test, thyroid clearance rate thyroid suppression test, perchlorate discharge test, uptake of radiolabel T3 by red cells, T3 charcoal test.

^{131}I therpapy for treatment of hyperthyroidism, throid follicular carcinoma.

^{125}I applications: Radio-immuno assays of T3, T4, TSH and other hormones, uptake by thyroid and treatment of thyroid disorders

^{123}I applications

^{99m}Tc applications in medical imaging of different organs and dynamic /function studies.

^{201}Tl – myocardial perfusion imaging, 67Ga for scintigraphy of tumors and infections,

Radonuclides in therapy- ^{89}Sr, ^{186}Re-HEDP, ^{153}Sm-EDTMP, lutetium-177

RADIATION PROTECTION (15 lectures)

Principles of radiation protection – Quantities used in radiation protection, Justification of practice, optimization of protection and Individual dose and risk limits, regulatory aspects of radiological safety, Control of internal and external hazards..

Radioactive waste disposal - decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, decontamination of person, decontamination of room Radioisotopic waste, general principles, liquid and solid waste, , disposal of solid, liquid and gaseous effluents/ waste, decaying storage transfer to authorized personal, management of sealed and unsealed sources.

Transport of radioactive material - storage and transport of waste, transport index.

Introduction to designing of radiation laboratory: Classification of radiation labs, design of areas for radioisotope laboratories, criteria for grading laboratories using unsealed radioisotopes,

STOCHASTIC AND NONSTOCHASTIC EFFECTS OF RADIATION (3 Lectures)

Late effects in normal tissue systems and organs, radiation carcinogenesis, mechanism of radiation carcinogenesis, risk of carcinogenesis, animal and human data, shortening of life span, genetic effect of radiation, factors affecting frequency of radiation induced mutations, dose effect relationship, pre-natal effects of radiation, types of genetic disorders, risk estimation, direct method, doubling dose method, uncertainties.

Books:

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

1. Radiation Biology (Prentice Hall) P.A. Casserette
2. Introduction to Radiation Biology by, 3rd ed. (BI Churchill Livingstone). P. Uma Devi, A Nagarathnam and B.S. Satish Rao :
3. Radiation Safety for Unsealed Sources 2nd ed. (Himalaya Publishing House). G. S. Pant
4. Radiation Biology for the Radiologists, 6th ed. (JP Lippincott Company). Eric J Hall
5. An Introduction to Radiation Protection in Medicine (Taylor and Francis). J. V. Trapp and T. Kron
6. Fundamentals of Nuclear Pharmacy 5th ed. (Springer). Gopal B. Saha
7. Physics and Radiobiology of Nuclear Medicine 2nd ed. (Springer). Gopal B. Saha

List of Practicals in First year

1. To identify different parts of a human skeleton and to visualize microanatomical view of epithelial tissue , musculoskeletal system, Respiratory system, Digestive system, Urinary system, Reproductive system,(Male & Fernale), Nervous system using light microscope.
2. To determine TLC, red blood cell counts using hemocytometer
3. To study DLC in blood smear.
4. Demonstration of SPSS statistical software, Matlab statistical software & Excel and Power point
5. To measure Half Value Layer's of β and γ emitters and determine linear mass absorption coefficients.
6. To study self-absorption and back scatter using beta emitting radioisotopes.
7. To determine absorption coefficients of biological tissues with β and γ radioactive sources of different energies.
8. To identify the unknown radionuclides from a mixture of two radionuclides.
9. To study the statistics of radioisotopic measurements and observe the effect of background on the counting statistics.
10. To determine the half lives of radioactive isotopes.
11. To find out the spectrum of energies emitted by a radioisotope by using gamma ray – spectrometer.
12. To determine the energy resolution of spectrometer and effect of scatter in source volume.
13. To identify unknown radionuclide on the basis of its principal energy by using spectrometer.
14. Gamma ray spectrometry with a single channel analyzer.
15. Effect of EHT and gain on spectrometer using a mixture of two radionuclides.
16. To determine the plateau and efficiency of GM tube and find out the dead time/ resolving time of GM counter
17. Use of gamma ray scintillation counter for measuring in vivo thyroid uptakes following administration of carrier-free ^{131}I.
18. To study the influence of carrier on in- vivo uptake carrier free ^{131}I by the thyroid.
19. To find out the bio-distribution of a given radionuclide in a given animal.
20. To label the red blood cells using ^{51}Cr and to determine the efficiency of labeling.
21. To find out the average life span of red blood cells by using ^{51}Cr radionuclide.
22. To determine the blood volume of a given animal using ^{51}Cr labeled red blood cells.
23. To measure the blood volume using ^{99}Tc labeled red blood cells.
24. To prove that spleen is the storehouse of worn out red blood cells by using ^{51}Cr labeled red blood cells.
25. To find out the target / non target ratio of ^{99m}Tc labeled pharmaceuticals.
26. To determine the biological half life of $^{99m}Tc\ O_4^-$ and labeled pharmaceuticals.

List of Demonstrations in First year

1. To measure AC voltage signal and its frequency using an oscilloscope and to study NPN & PNP transistor and characteristic of multivibrator.
2. To use an Oscilloscope as a display for studying the half wave rectifier and to set up LC filter circuit, L and C filter circuits and study the waveform obtained on the oscilloscope. Find the ripple factor in each case.
3. Two stage RC coupled amplifier - frequency response.
4. Construction of a voltage multiplier.
5. Characteristics of a regulated power pack.
6. OPAMP circuits - Inverting and non inverting amplifiers.
7. Integrator and differentiator circuit using OPAMP.
8. To demonstrate ECG in normal and treated animals.
9. To demonstrate electrical impedances in biological tissues

SECOND YEAR

(35 Lectures)
Paper I- NUCLEAR MEDICINE IMAGING AND COUNTING INSTRUMENTATION

Rectilinear scanner and Photography (4 Lectures)

Basic problems: Collimation, scattering and attenuation, block diagram, principle of working, effect of scanning speed, dot factor, time constant, line spacing, film density, information density, photo recording display, contrast enhancement and clinical applications.
Structure of an x-ray film, single and double emulsion films, types of films, cross over effect. Characteristic curve of a photographic emulsion, variations in characteristic curve with development, use of filter color, UV and Polaroid

Gamma Camera (11 Lectures)

Basic principles of gamma camera, collimators - parallel hole, divergent, convergent pinhole, fan beam, slant hole collimator. NaI (Tl) detector, position determining circuits, display. Gamma camera-computer interface- ADC/DAC. Performance characteristics and image quality.
Criteria of installation of Gamma camera. Selection of gamma camera – specifications and other aspects, automatic acquisition of images. Purchasing and monitoring equipment performance. , trouble shooting.
Gamma camera for PET imaging.
QC OF GAMMA CAMERA: Gray scale calibration, uniformity, tuning of camera, spatial distortion and resolution, Phantoms for QC, software phantoms, Internet based QC

SPECT (Single photon emission computerized tomography) (10 lectures)

Theory aspects, rotating gamma camera and the couch, single or multiple section devices multi detector SPECT, Data collection: SPECT v/s planar camera, SPECT acquisition – step & shoot/continuous, matrix selection, rotating arc selection. Image reconstruction techniques, filters, artifacts in SPECT (attenuation correction, non-uniformity corrections, correction with combined SPECT-CT system), effect of scatter & scatter correction, noise, partial volume effects. Performance characteristics

Probe Systems (3 lectures)

Gamma probe, Thyroid uptake probe, basic components, system set-up and calibration, flat field collimator, iso-response curve and working distance. QC of uptake probe.

Dose calibrator (2 lectures)

Principles and its applications, QC of Dose calibrator

Instruments in Radiation Safety (5 lectures)

Principle and uses of Ionization chambers, proportional counters, GM tubes

SECOND YEAR

(60 Lectures)

Paper II- Principles and Practice of Radiological Protection, Radiation Dosimetry, Radiobiology and Hospital Practice

General principles of radiation protection (15 lectures)

Principles of radiation protection, specific factors involved in radiation protection- time, distance, shielding. Quantities and units: Dose, roentgen unit of exposure, radiation sensitivity of biological materials, radiation absorbed dose (RAD, Gray), radiation weighting factor , Relative biological effectiveness (RBE), Quality factors, Roentgen Equivalent man (REM), Sievert , equivalent dose , effective dose, collective equivalent dose, total effective dose equivalent, radiation dose limits, maximum permissible doses- (IRCP recommendations) Natural radiation exposure, cosmic radiation, terrestrial radiation , nuclear fall outs, medical exposures. Basis for exposure limits for occupational exposure, ALARA, exposure of embryo /fetus younger persons, occupational exposures, members of the public, dose limits for patients, risks associated with recommended limits. Deterministic and stochastic effects, the concept of comparative risk. Dos and Don'ts in radiation protection practice. Personal monitoring, film badges, TLD badge, use of survey meters and dose calibrators, use of dose constraints for staff and pregnant women. ICRP and National radiation safety standards.

Radioactive decontamination and waste disposal (3 lectures)

Radioactive decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, .decontamination of person, decontamination of room

Radioisotopic waste, general principles, liquid and solid waste, storage and transport of waste, disposal of solid, liquid and gaseous effluents/ waste, decaying storage transfer to authorized personal, management of sealed sources, quality management program, administration/misadministration of radiopharmaceuticals, release of patients administered with radiopharmaceuticals.

Regulatory Aspects & Licensing (5 lectures)

The Atomic Energy Act, Rules issued under the Act, Surveillance procedures issued under the Rules, Notifications issued under RPR, 1971, AERB Safety Directive, Safety code for NM facility, Duties of Medicalphysicist/Technologists/ Radiopharmacists/RSO, Regulatory clearance-Approval of NM Lab, Physician & RSO, Regulatory consent, authorization- for disposal of radioactive "waste and safe transport of Radioactive materials. Ethics, Registration of radiopharmaceuticals and their use. Historical background of legislation in the atomic energy field, need for control of radiation exposure at national and international levels, national control through acts with supporting regulation at central and state levels international control through specialized agencies, third party liability andinsurallce in the atomic energy field; ICRU and ICRP Recommendations; on Dose Limits, Protection Regulations, Basic Framework of Radiation Protection, Radiation Safety Program, Radiation Safety Officer and duties of Radiation. Safety Officer, Radiation Safety Committee, Personnel Monitoring, Responsibilities for Implementation of Basic Safety Standards Requirements. Relevant codes for X-ray and radiation therapy, licensing procedures under atomic energy (radiation protection) rules.

Role of National and International Organizations like AERB, MCI, NMC, BRIT, BARC, IAEA, ICRP

Transportation of radioactive substances (3 Lectures)

Historical background, classification of radioactive materials, general packing requirements, transport documents, labeling and marking of packages, testing and approval of transport container for radioactive materials, Transport of large radioactive sources and fissile material, exemptions from regulations, trallsport emergencies, Regulations for different modes of transporting radioactive material including transport by post.

Radiation Dosimetry (10 Lectures)
Radiation dosimetry for external radioactive source and internally deposited radioactive dose; compartment analysis; Single Compartment, Two Compartment model, beta particle dosimetry; Equilibrium Dose rate equation, Calculation of Beta dose.
Gamma dose calculation, Specific gamma ray constant (Γ), Geometrical factor and average geometrical factor. MIRD method of internal dose calculation. Absorbed Fraction and calculation of absorbed fraction, calculation of dose. age dependent dose coefficient for various radiopharmaceuticals. Dosimetric considerations in isotope therapy.

Potential Exposure and Emergency Plans (5 lectures)
Potential exposure and safety assessment, Mitigation of consequences: emergency plans – Lost source, Stuck source, Contamination, Off-site accidents, Patient accidental exposure: Radiation emergencies, preparedness and record keeping, Large scale spillage, "leakage of radioactivity substance to environment, accidental inhalation, death of a patient with radioactivity etc.

Transportation of PET Radiopharmaceuticals (2 lectures):
Practice as per AERB guidelines and recommendations of international regulatory bodies

Radiation Biology (10 Lectures)
Biological effects of ionizing radiation, stochastic and non-stochastic effects, genetic effects, somatic effects, effects in-utero.

Design of Radiation Centers (2 lectures)
Design and safety aspects of planning a Nuclear medicine department, cyclotron facility and PET centre, Design of laboratories or various sizes & capacity as per the norms of BARC. Design of radiation labs, types of labs, Security of Sources and radioactive cautions signs and labels.

Patient Care and Hospital practice (5 Lectures)
Behavioral science (Care of the patient): Management of ambulatory and non-ambulatory patients and aids for this, elementary hygiene and cleanliness, nursing care, first aid, principles of asepsis- handling of contaminated swabs, used syringes and needles, handling of secretions, sterilisation methods, preparation of patients for general nuclear medicine procedures, precautions-administration of radiopharmaceutical to children, nursing and care taking mothers and pregnant women

- Planning & scheduling of the patient work load.
- Economic aspects of nuclear medicine and cost-effectiveness of nuclear medicine procedures.
- Public relations.
- Regular participation in weekly journal club, Seminar and other periodical CME programs.

Neutron activation analysis (NAA), radiomicrobiology, fluorescent scanning etc

SECOND YEAR
(65 Lectures)

Paper III- Principles and Practice of Radio pharmacy, Radionuclide Generators & Radiopharmaceuticals

Regulatory Constraints (3 Lectures)

Regulatory constraints: pharmaceutical aspects, radiation protection aspects, local constraints, Regulations, ethics and registration of radiopharmaceuticals
Design of hospital pharmacy, laboratories, radionuclide stores.

Radionuclide production and characteristics (10 Lectures)

Production of radioisotopes by artificial methods – reactor produced, cyclotron produced radionuclide generators. Physical & chemical characteristics of radionuclides used in nuclear medicine, Criteria for selection of the radionuclides for diagnosis and therapy. Short-lived radionuclide generators: ^{99}Mo-^{99m}Tc, ^{188}W-^{188}Re, ^{113}Sn-^{113m}In, ^{68}Ge-^{68}Ga: ^{82}Sr-^{82}Rb, ^{81}Rb-^{81m}Kr Radionuclide generator system: principles of generator system, Parent-daughter equilibrium. Solvent extraction, liquid column generator, solid column generator, elution efficiency and factors affecting elution yield. Performance and quality control of Mo99/Tc99m generator.

Design and development of radiopharmaceuticals (5 lectures)

Characteristics of Ideal radiopharmaceutical, general considerations, factors affecting the design of radiopharmaceuticals: compatibility, stoichiometry, charge and size of the molecule, protein binding solubility, stability and bio-distribution. Important factors in labeling, efficiency of labeling process, chemical stability of the product, denaturation or alteration, isotope effect , storage conditions, specific activity, radiolysis, purification analysis, shelf life. Cold kit preparation & contents, lyophilization techniques.

Specific methods of labeling (5 lectures)

Methods of radiolabelling : isotope exchange reactions, introduction of foreign label, labeling with bi-functional chelating agents, biosynDissertation/Project Work , recoil labeling, excitation labeling , substitution reactions.
Radio iodination: Principle of radio-iodination, methods of radio-iodination: Monocholoride method, chloramines T method, Electrolytic method, enzymatic method, conjugation method, demetallation method, iodogen method, iodo bed method, radioiodinated compounds, radioiodination of proteins, antibodies/monoclonal antibodies. Labeling with Tc99m: Tc99m chemistry: Technetium complexes, role of reducing agent in Radiolabeling, technetium coupling with biologically active modules. Precursors and chelating agents needed for the labelling of Biomolecules, cellular labeling with Tc99m chelates .
Labeling with ^{111}In: labeling of leucocytes and platelets, antibodies, ^{111}In-penteterotide,

Quality control of radiopharmaceuticals (8 Lectures)

Determination of chemical purity, determination of tin(ll) ,Determination of radiochemical purity, determination of radionuclide purity, sterility testing of radiopharmaceuticals, pyrogen testing of radiopharmaceuticals, bio-distribution studies
Physicochemical tests: physical characteristics, pH and ionic strength,
QC for ^{99}Mo/ ^{98}Mo(stable molybdenum) by performing breakthrough tests : Breakthrough of Methyl ethyl ketone, alumina.
QA of PET *radiopharmaceuticals* by TLC scanner, HPLC and *Gas Chromatography (GC).*
QC in hospital radiopharmacy practices - includes aseptic practices & pharmaceutical safety aspects. Good manufacturing practice (GMP), ISO and ISI standards in radiopharmaceuticals.

Physicochemical techniques: (4 lectures)
Principle of purification and separation of molecular components in Low pressure open chromatography, (TLC, paper, column) HPLC, gas chromatography. Basic principle and application of Mass spectroscopy, Nuclear magnetic resonance spectroscopy (NMR), flow cytometry in nuclear medicine.

Characteristics of Specific SPECT radiopharmaceuticals: (10 Lectures)
Chemical name, oxidation state of Tc99m and structure of Tc99m complex formed, cold kit specifications, amount/volume/size of the contents, labeling procedure, physical and chemical characteristics of radionuclide used for labeling, clinical applications of the radiopharmaceutical, quality control, pharmacokinetic data, radiation dose. Mechanism of localization of following radiopharmaceuticals in different organs.

99mTc-Sodium Pertechnetate
99mTc-Labeled Human Serum Albumin
99mTc-Macroaggregated Albumin
99mTc-Phosphonate and Phosphate Radiopharmaceuticals
99mTc-Sulfur Colloid
99mTc-Albumin Colloid (Nanocolloid)
99mTc Pentetate (DTPA)
99mTc-Mercaptoacetylglycylglycylglycine (MAG3)

99mTc-Dimercaptosuccinic Acid (DMSA)
99mTc-Labeled Red Blood Cells
99mTc-Iminodiacetic Acid Derivatives
99mTc-Hexamethylpropylene Amine Oxime.
99mTc-Ethyl Cysteinate Dimer.
99mTc-Sestamibi.
99mTc-Teboroxime.
99mTc-Tetrofosmin.

123I- or 131I-Metaiodobenzylguanidine (MIBG)
201Tl-Thallous Chloride

Characteristics of PET radiopharmaceuticals: (15 lectures)
Clinical applications of the radiopharmaceutical, quality control, pharmacokinetic data, radiation dose. Mechanism of localization of following radiopharmaceutical in different organs.

^{18}F-Sodium Fluoride
^{18}F-Fluorodeoxyglucose (FDG)
^{18}F-Fluorodopa
^{18}F-Fluorothymidine (FLT)
^{15}O-Water
n-^{15}O-Butanol
^{13}N-Ammonia
^{11}C-Sodium Acetate
^{11}C-Flumazenil
^{11}C-Methylspiperone (MSP)
^{11}C-L-Methionine
^{11}C-Raclopride

^{82}Rb-Rubidium Chloride

Physical and chemical characteristics of Positron emitters ,synDissertation/Project Work of 18-FDG, $^{11}CO_2$, $^{13}NH_3$ and $H_2{}^{15}O$, recent trends in radiopharmaceuticals and search for novel SPECT and PET radiopharmaceuticals.

SECOND YEAR

(55 Lectures)
Paper IV- Nuclear Medicine Imaging Techniques.

Renal imaging studies: Diuretic renogram, captopril renogram, standard renogram, uretic reflux study, renal transplant studies, static renal study.

Bone imaging: Routine bone (whole body and spot) imaging, bone flow study, quantitative bone scan-sacroiliac quantitative study, 3-phase bone scans.

Liver-spleen study, bone marrow imaging, spleen imaging with denatured RBC's

Gastrointestinal study- Hepatobiliary imaging, Gall bladder dynamic studies using IDA compounds, gastric oesophageal reflux, gastric emptying time, biliary reflux, Meckel's diverticulum imaging, GI bleeding with ^{99m}Tc-RBC, Salivary gland imaging (static/dynamic)

Endocrine studies-Thyroid imaging and uptake (^{99m}Tc and ^{131}I), Perchlorate discharge test, T_3/T_4 suppression test, TSH stimulation test. ^{131}I whole-body imaging, parathyroid imaging, adrenal cortex imaging, ^{131}I-MIBG imaging, testicular imaging.

Lung imaging studies -Ventilation lung imaging studies using gases (^{133}Xe, ^{81m}Kr), Inhalation imaging using aerosols, aerosols generators, mucociliary clearance, COPD, Pulmonary permeability using DTPA, perfusion imaging (MAA, Microsphere) –pulmonary embolism.

Cardiac studies- static blood pool imaging, Rest/stress myocardial imaging, infarct imaging, MUGA, gated blood pool study, first pass study (shunt detection), ^{201}Tl imaging

Central nervous study- cerebral blood flow dynamic studies, static brain imaging, cisternography and ventriculoatrial and ventriculoperitoneal shunts.

Bone marrow : Radiopharmaceuticals and imaging techniques studies- red-cell mass estimation, RBC survival and sequestration studies, ^{51}Cr gastrointestinal blood pool loss study, plasma volume estimation using ^{125}I-HAS and Ferrokinetic studies.

Miscellaneous studies- ^{67}Ga imaging, Lacrimal scintigraphic imaging, Lymphatic imaging, adrenal imaging using ^{131}I-MIBG

PET studies (6 Lect) : Methods of performing PET/CT procedures in cardiology, Neurology and Oncology, Gated PET/CT studies (respiratory and cardiac gating). Use of ^{18}FDG and NH_3 for cardiac studies.

Oncology and nuclear medicine: molecular targets for cancer diagnosis, Clinical application of PET in oncology, cardiology and neurology, use of PET in treatment planning and to study treatment response

In vitro techniques: (14 Lectures) Principals of RIA, standard curve, data analysis, QC and applications. Methods of receptor assays, hormones, drugs, T3 charcoal uptake test RIA estimation – T3, T4, TSH and thyroid antibodies, thymoglobulin. Methods of receptor assays, hormones, drugs, Chemiluminiscence

Immunoradiometric assay (IRMA)- theory, operation and applications,

Enzyme linked immunosorbent assay (ELISA), Fluorescent immunoassay, Immune reactions useful in bioassays – precipitin reaction, immunodiffusion, complement fixation assay, agglutination. Immunoelectrophoresis – cross over and rocket elctrophoresis, Fluorescent activated cell sorting.

GFR plasma sample method

Gastricintestinal protein loss estimation using ^{51}Cr-chromic chloride, Vitamin B_{12} absorption study and Schilling Test, etc.

Red-cell mass estimation, RBC survival and sequestration studies, ^{51}Cr gastrointestinal blood pool loss study, plasma volume estimation using ^{125}I-HAS and Ferrokinetic studies.

SECOND YEAR

(37 Lectures)
Paper V- CYCLOTRON, RADIONUCLIDE THERAPY, IN-VITRO TECHNIQUES AND ALLIED INSTRUMENTATION

Cyclotron (4 Lectures)
Basic working principles and instrumentation of cyclotron, type of cyclotron, cyclotron generated radionuclides, cyclotron shielding, neutron detection and other quality control procedures.

Positron Emission Tomography (5 lectures)
Introduction, **PET and coincidence detection:** Basic principles of PET imaging, Pet detector and scanner designs detectors – BGO, NaI (Tl), LSI; Attenuation correction with transmission sources – ^{68}Ge, ^{137}Cs. Data corrections: normalization, uniformity correction, scatter correction, random correction. 2-D and 3-D reconstructions, performance characteristics of PET imagers. Daily, weekly and monthly Quality control of the PET/CT.

PET v/s SPECT, Dedicated and hybrid PET systems. Performance characteristics, Modeling and quantification in PET.

Computed Tomography (3 Lectures)
Principles of Tomography, longitudinal and transverse or axial tomography, multisection radiography. Principles of CT, design of equipment, reconstruction of algorithms and various biomedical applications. CT QC.

Therapeutic applications of radionuclides (14 Lectures)
Treatment of bone pain: use of 32P-orthophosphate, 99Sr- Strontium chloride, 186Re-HEDP, 153Sm-EDTMP. Radioimmunotherapy. Pre and post therapy imaging and patient preparation, Radiation Synovectomy, Treatment of hyperthyroidism, thyroid cancer whole body imaging – use of ^{131}I.
Treatment of polycythemia Vera and leukemia. Treatment of malignant effusion in pleural and peritoneal cavities
Advances in Radionuclide Therapy.

MR/CT/Ultrasound imaging (3 Lectures)
Physics of magnetic resonance, magnetic resonance imaging, MRI equipment and principle, its advantage over CT/ Ultrasound, functional magnetic resonance imaging, limitations and uses of MRI.

Fusion imaging (3 Lectures)
Definition, introduction, Software and hardware fusion of images
SPECT/ CT Fusion Imaging: Principles, applications, limitations and uses
PET/CT Fusion Imaging: Principles, applications, limitations and uses

Use of CT, PET and SPECT for imaging of small animals. Animal conditioning, dynamic studies and other applications of multimode PET+SPECT+ CT.

Internet In NM, Telemedicine & Nanotechnology (5 Lectures)
Communication protocols: standard used, FTP, TCP/IP protocols, DICOM and interfile conversion software, PACS, Telemedicine infrastructure-software and hardware used, Remote sensing telecommunication, information technology, challenges to telemedicine and Medical applications of Telemedicine. Demonstration in MTLAB® and Mathematica® software packages;
Nanotechnology: Concepts and its biomedical applications

List of Practicals in Second year

1. Perform the calibration of Uptake Probe.
2. Determine the isoresponse curve for the flat field collimator.
3. Perform Quality Control of Dose Calibrator.
4. Determine the half life of a radionuclide with the help of a Dose Calibrator.
5. Evaluate the geometric/volumetric variation of the radioactivity using Dose Calibrator.
6. Determine the Intrinsic uniformity and extrinsic uniformity of Gamma Camera.
7. Perform experiment to determine the spatial resolution and linearity of Gamma Camera.
8. Determine the COR of the Gamma Camera.
9. Devise an experiment to measure the Pixel size for 128X128 and 256X256 matrix size of the Gamma Camera.
10. Determine the Dead time by two sources method and determine count rate at 20 % count loss.
11. Determine the system sensitivity with different collimators.
12. Perform the total performance test on the SPECT gamma camera.
13. Radiation exposure: effect of distance, Shielding and time.
14. Study of energy dependence of a pocket dosimeter and a survey meter
15. Monitor the given item for contamination, through wipe test, if found contaminated, then perform the Decontamination using contamination monitor.
16. Calculation of shielding for a given radionuclide
17. To separate ^{99m}Tc from ^{99}Mo and determine the efficiency of extraction.
18. Perform the quality control of elute from 99Mo-99mTc Generator.
19. To determine the Rf of ^{99m}Tc and the given labeled compounds by using ascending chromatography.
20. Perform the Radiochemical Purity of the given radioparmaceutical, using Paper chromatography.
21. Prepare vial kit preparation of radiopharmaceutical.
22. QC of PET Radiopharmaceuticals (RCP by thin layer chromatography Scanner, gas chromatography and Bacterial endotoxin).
23. Quality Control of Tc99m radiopharmaceuticals.
24. Perform experiment to calibrate PET/CT
25. To perform an Iodine-131 whole body survey scan
26. To demonstrate Iodine-131 therapy in a thyroid cancer patient
27. To demonstrate monitoring and discharge from the ward of a high dose Iodine 131 patient
28. To demonstrate and monitor iodine therapy for thyrotoxicosis.

List of Demonstrations in Second year

1. Demonstration of transport of radioactive materials.
2. Emergency preparedness drill.
3. Demonstration of TLD badges, Pocket dosimeters.
4. To perform Radiation survey around the cyclotron and Radio-iodine therapy Ward.
5. Demonstrations regarding the calculations of exposure doses and safety aspects
6. Demonstration of scheduling of patients
7. To prepare layout plan for different types of nuclear medicine laboratories
8. Designing of a PET department depending upon number of patients per week
9. Demonstration of ^{99}Mo-^{99m}Tc column generator.
10. Demonstrations of Bone scan (3-phase, whole body and statics)
11. To perform MPI.
12. To perform Lung perfusion study
13. To perform Renogram study (using DTPA/EC)
14. To perform DMSA scan
15. To perform DRCG
16. To perform Gated Blood pool scintigraphy.
17. To perform Salivary scintigraphy
18. To perform Solid GET
19. To perform GER
20. To perform Liver scan using SC
21. To perform Hepatobillary study.
22. To perform Brain SPECT study
23. To perform adrenal imaging using iodine 131 MIBG
24. TO perform thyroid scan
25. To perform parathyroid scan
26. To perform whole body Iodine-131 scan
27. To perform RAIU
28. Perform synDissertation/Project Work of 18-F FDG.
29. To set a protocol for PET imaging for Oncology patient
30. To set a protocol for PET imaging for cardiac viability study
31. Demonstration of methods of acquisition of PET/CT procedures in cardiology, Neurology and Oncology.
32. Demonstration of Cyclotron
33. Perform preconditioning of cyclotron
34. Perform beam targeting experiment in cyclotron
35. Perform synDissertation/Project Work of 18-F FDG
36. Demonstration of SPECT/ CT Fusion Imaging principles.
37. Demonstration of PET/CT Fusion Imaging principles.

Suggested Books and Journals

Note: The books indicated as text-book(s) are suggestive of the level of the coverage. However, any other book may be followed.

Name of Book	Editor's Name
• Cell & Molecular Biology	De Robertis
• Molecular Biology of the Cell	Alberts, Bray, Lewis, Raff
• Molecular Biology of Gene	Watson
• Gene –V	Benzamin
• Cell Signaling	Morgan
• Recombinant DNA	Tooze, Tustz
• Text Book of Medical Physiology	Guyton
• Physiology	Chatterjee
• Biochemistry	Lehninger
• Biochemistry	Stryer
• Basic Medical Biochemistry	Smith Marks & Libermann
• Biochemistry	Harper
• Text Book of Microbiology	Panikar
• Methods in Biostatistics	Mahajan
• Methods of Biostatistics	Bhaskararao
• Statistical and Mathematical Techniques in NM	GS Pant
• Biostatistics: A foundation for the analysis in the Health Sciences	Wayne W. Daniel:, John Wiley.
• Fundamental of Statistics Vol.-I & II	A.M.Goon, M.K.Gupta & B.Das
• Essentials of Medical Statistics, Blackwell publishers	Betty Kirkwood
• Object Oriented Programming with C^{++}	E.Balaguruswamy.
• A First Course in Computers	Sanjay Saxena.
• Calculus (Pearson Education, 2003)	G.B.Thomas and R.L.Finney
• Introduction to Mathematical Physics	C.Harper (Prentice Hall of India)
• Field and Wave Electromagnetics	David Cheng
• Principles of Applied Biomedical Instrumentation	Geddes, Baker
• Mathematical Models in Biology –An Introduction	Allman & Rhodes
• Radiation detection	Knoll
• Handbook of Health Physics and Radiological Health	Shleien, Slaback, Birkey
• Physics and Radiobiology of Nuclear Medicine	Gopal Saha
• Radiation Biology	Casarett
• Elements of Radiobiology	Selman
• The essential Physics of Medical Imaging	Bushberg, Seibert, Leidholdt
• Physics in Nuclear Medicine	Cherry, Sorenson, Phelps
• Medical Imaging Physics	William R.Hendee
• Introduction to Medical Physics	Arid
• Medical Physics	Cameron
• Advances in Diagnostic Medical Physics	Pant GS
• Quality Controls of NM Instrumentation	Pant GS
• Quality Control in NM, Radiopharmaceutical, Instrumentation &In-vitro Assays	Rhodes Buek
• Radiation Safety for unsealed Sources	Pant GS
• Radiation Dosimetry	Attix, Poesch
• Fundamentals of Nuclear Pharmacy	Gopal Saha

• Radiopharmaceuticals	Gopal Subramaniam
• Text Book of Radiopharamcy	Sampson
• Radio immunoassay Principles & Practices	Pillai & Bhandarkar
• Nuclear Medicine in Vitro	B. Rothfield
• Principles of Nuclear Medicine	Henry N. Wagner (Jr.)
• Nuclear Medicine Technology and Techniques	Bernier,Christian, Langan
• Principles & Practice of Nuclear Medicine	Early & Sodee
• Basics of PET Imaging	Gopal Saha
• PET and PET/CT in Oncology	Pehr, Biersack, Coleman
• Nuclear & PET Techniques	Christian
• Interventions in Nuclear Medicine	Richard P. Spencer
• An Atlas of Clinical Nuclear Medicine	Fogelman & Maisey
• Clinical SPECT Imaging	Elissa Lipcon Kramer

Safety Codes

- AERB Safety Manual and AERB Safety Guide
- AERB Safety Code (Nuclear Medicine Laboratories)
- AERB Safety Code (Transport of Radioactive Materials)
- AERB Safety Guide (Standards of Safety in Transport of Radioactive Material)
- AERB Safety Guide (Procedure for Forwarding, Transport, Handling and Storage of Radioactive Consignments)
- IAEA activities in Nuclear Safety by IAEA

Journals

- International journal of radiation application instrumentation-part B
- Nuclear Medicine and Biology
- Medical Physics
- Journal of Nuclear Medicine Technology
- Journal of Nuclear Medicine
- European Journal of Nuclear Medicine
- Seminars in Nuclear Medicine
- Nuclear Medicine Annual
- World Journal of Nuclear Medicine
- Annals of Nuclear Medicine
- Indian Journal of Nuclear Medicine
- Hellenic Journal of Nuclear Medicine

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