BABA FARID UNIVERSITY OF HEALTH SCIENCES

Annexure – D as per agenda item no. 9

revised Ordinance-cum-Syllabus for M.Sc. Nuclear Medicine course from the academic session 2019-20 & onwards according to semester 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

Baba Farid University of Health Sciences, Faridkot, Punjab (India)

Faculty of Medical Science

Revised Ordinance cum Syllabus

For

M.Sc. Nuclear Medicine

(Session 2019-2020)

total 67 pages

INTRODUCTION

- Nuclear Medicine is an established clinical and research specialty with a wide ranging diagnostic and therapeutic techniques. It can be defined a discipline embracing all applications of radioactive materials in the diagnosis and treatment of various diseases, in medical research and in the study of body functions, both in healthy and diseased state. As this is a specialized branch of medicine and is multidisciplinary in nature, it requires skilled / trained manpower. Therefore, M.Sc. Nuclear Medicine syllabus has been prepared in such a way that it will make the student a good nuclear medicine physicist, researcher and a teacher after qualifying this course. There are a number of medical institutes in Punjab; it was observed that none of these institutes gives nuclear medicine degree in Punjab. Moreover a few of institutes provide this degree course in India. We have also observed a shortage of skilled manpower in the nuclear medicine field. Therefore we have proposed a Nuclear Medicine degree in our University to meet the need of trained nuclear medicine professionals.

AIMS AND OBJECTIVES

- The postgraduate training program is aimed at developing highly skilled technical manpower in Nuclear Medicine. After completion of the course, the trainee should be able to demonstrate high standards of professional skills and competence/leadership qualities in the field of Nuclear Medicine.

DURATION OF COURSE

- The duration of the program of Master of Science in Nuclear Medicine will be two Academic Years (Two Semesters in each year.)

NUMBER OF SEATS

- Number of Seats = 05

ADMISSION CRITERIA:
ELIGIBILITY/QUALIFICATION

a) This course shall be open to a candidate who has passed B.Sc. Non-Medical/Medical with first class from a recognized university with Physics and Chemistry (Non-medical Stream) or Chemistry & Zoology/Botany (Medical Stream) as core subjects. The candidates who studied B.Sc. through correspondence and Open University stream are not eligible.

b) Candidates having B.Sc. in Nuclear Medicine/Biophysics with first class from a recognized university shall also be eligible for admission to the course.

AGE LIMIT FOR ADMISSION:

- A candidate should have completed the age of 20 years at the time of admission or would complete the age on or before 31st December on the year of admission to the first year M.Sc. (Nuclear Medicine) course.

PHYSICAL FITNESS CERTIFICATE:-

- Every candidate before admission to the course shall submit to the Head / Director of the Institution a certificate of medical fitness from an authorized medical officer that the candidate is physically fit and mentally sound to undergo the academic course and does not suffer from any disability or contagious disease.

CUT-OFF DATES FOR ADMISSION TO THE EXAMINATION:-

- The Candidates will be admitted in June-July session of Academic Year and will be registered to take up their first year M.Sc.(Nuclear Medicine) Degree course after fulfillment of the regulation.

REGISTRATION:

- A candidate admitted to the M.Sc. (Nuclear Medicine) degree course shall register his/ her name by submitting the prescribed application form for registration duly filled in by remitting the prescribed fee to the BFUHS within 30 days from the cutoff date prescribed for M.Sc. (Nuclear Medicine) degree course.

DURATION OF THE COURSE: - (TWO YEARS)

- The duration of certified study for the M.Sc. (Nuclear Medicine) shall extend over period of two academic years.

COMMENCEMENT OF THE COURSE:-

- The course will commence from 2019 -2020 of the Academic Year.

COMMENCEMENT OF EXAMINATION:

- As per Examinations rules of BFUHS, If the date of commencement of the examination falls on Saturdays, Sundays or declared Public Holidays, the examination shall begin on the next working day.

CARRY OVER OF FAILED SUBJECTS:-

The Candidate is permitted to go to the next semester failing 50% of total subjects appeared in that semester. But he/she will not be permitted to appear for 4th semester exam unless all the subjects from all the 3 semesters are cleared.

CURRICULUM:

- The Curriculum and the Syllabus for the course shall be as prescribed by the standing Academic Board from time to time.

MEDIUM OF INSTRUCTION:

- English shall be the medium of instruction for all the subjects of study and examination of the M.Sc. (Nuclear Medicine) Degree course.

WORKING DAYS IN AN ACADEMIC YEAR: -

- Each academic year shall consist of not less than 270 working days as per Regulation of this University.

Total No. of days in a year	**365 days**
No. of weekly off (Sundays)	- 52 days
No. of Government Holidays	- 22 days
No. of Holidays	- 21 days
	-95 days

Total No. of working days including	270 days
examination period	---

ATTENDANCE REQUIREMENT FOR ADMISSION TO EXAMINATION:-

- In the first year the candidate should have 75% of attendance in Theory and practical before appearing for the exam.

- No candidate shall be permitted to any one Examination of M.Sc. (Nuclear Medicine) unless he / she has attended the programme for the prescribed period in the institution and produces the necessary certificate of study, attendance and progress from the Head of the institution.

- A candidate lacking in the prescribed attendance and progress in any one subject in theory or practical in the first appearance shall not be permitted to appear for the entire examination.

- Attendance earned by the students should be displayed on the Notice Board of the college at the end of every 3 months and copy of the same should be sent to the University and parents of the students concerned.

CONDONATION OF LACK OF ATTENDANCE:

- As per BFUHS guide book.

INTERNAL ASSESSMENT MARKS:-

- The Internal Assessment should consist of the following points for Evaluation:-

  i) Theory

  ii) Seminar / assignment / conference

  iii) Journal club discussions

  iv) Practical / Clinical

  v) Viva voce

- The Internal Assessment of the candidate has to be assessed on the above points and a report has to be submitted by the institution as detailed below:-

- The aggregate of Final Internal Assessment Marks should be submitted 2-months before the commencement of the exam as per scheme of examination shall be taken by the University as Internal Assessment Marks and minimum of 50% marks is mandatory for permitting the candidates to sit for the University examinations.

DISSERTATION & EVALUATION:-

- The topic of the dissertation should be submitted before starting of the 2nd year of the course. The candidate should also inform the name of the supervisor for the dissertation to the University while submitting the dissertations topic.
- The dissertation should be submitted duly signed by the Supervisor and Head of Department of Department of Nuclear Medicine and the same has to be forwarded to the Controller of Examination through the Head of the Institution two months prior to the Examination.
- For dissertation marks 150, Viva-voce on dissertation/Presentation mark 50 and Seminar / Internal Assessment 70 - Minimum mark to pass 50% (Dissertation+ Viva+ Seminar/Internal Assessment).
- If the dissertation is not approved by the majority of the examiners, the results shall be withheld till the resubmitted dissertation is approved.
- If the candidate fails in the Written / Practical Examination, but his / her dissertation is approved, the approval of the dissertation shall be carried over to the subsequent examination.

MAINTENANCE OF LOG BOOK:-

- Every Post Graduate candidate shall maintain a record of skills (Log Book) he / she has acquired during the two years course period, certified by the various Heads of Department, where he / she undergoes training.
- The candidate is also required to participate in the teaching and training program for the under-graduate students.

- In addition, the Head of the Department shall involve their Post-graduate students in Seminars, Journal Group Discussions and participation in Conferences.
- The Head of the Department shall scrutinize the Log Book once in every three months.

AWARD OF DEGREE:-

- The degree shall be awarded by the University only after the successful completion of the course

AWARD OF MEDALS / PRIZES:-

- The University shall award at its Convocation, medals and prizes to outstanding candidates as and when instituted by the Donors as per the schedule prescribed for the award.

QUALIFYING MARKS FOR PASS :-

- 50% of marks in University theory Examination ;
- 50% of marks in University Practical examination and
- 50% of aggregate marks in Theory, Internal Assessment, Practical and Oral Examination.

RETOTALLING OF ANSWER PAPERS:-

- Re-totaling is allowed in the failed subjects.

NUMBER OF APPEARANCE / COMPLETION OF THE COURSE OF STUDY:

- A candidate registered for two year M.Sc. (Nuclear Medicine) Course must qualify in the examinations within three years from the date of his / her admission.

RE-ADMISSION AFTER BREAK OF STUDY:

- As per the procedure laid down in a common regulation for all the courses of the BFUHS, Medical University.

MIGRATION / TRANSFER OF CANDIDATES:-

- Request for Migration / Transfer of candidates during the course of study from one recognized Institution to another recognized Institution of this University or from other University shall not be granted under any circumstances.

VACATION:-

- No Vacation for Post Graduate Degree Courses of this University.

AUTHORITY TO ISSUE TRANSCRIPT:-

- The Controller of Examinations shall be the authority for issuing transcript of marks after remitting the prescribed fee.

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.

FIRST YEAR

First Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
MSCNM-101T MSCNM-101P	Basic concepts of Human Anatomy and Cell physiology	75	40	115
MSCNM -102T MSCNM -102P	Human Physiology, Immunology and Cancer biology	75	40	115
MSCNM -103T MSCNM -103P	Radiation Physics	75	40	115
MSCNM -104T MSCNM -104P	Radiation Biology and Radiation Chemistry	75	40	115
INTERNAL ASSESSMENT				**40**
				Total = 500 Marks

Second Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
MSCNM-201T MSCNM-201P	Radiation Detection and Measurements	75	40	115
MSCNM-202T MSCNM-202P	Basic concepts of Electronics, Biomedical instrumentation andTechniques	75	40	115
MSCNM-203T MSCNM-203P	Applied Mathematics, Biostatistics and Computer applications	75	40	115
MSCNM-204T MSCNM-204P	Radioisotopes application and Radiation Safety	75	40	115
INTERNAL ASSESSMENT				**40**
				Total =500 Marks

SECOND YEAR

Third Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
MSCNM-301T MSCNM-301P	Nuclear Medicine Instrumentation	75	40	115
MSCNM-302T MSCNM-302P	Principles and Practice of Radiopharmacy	75	40	115
MSCNM-303T MSCNM-303P	Basic concepts of Radiological Protection & Dosimetry	75	40	115
MSCNM-304T MSCNM-304P	Nuclear Medicine Imaging (SPECT/CT)& Non-imaging Techniques	75	40	115
	INTERNAL ASSESSMENT			40
				Total = 500 Marks

Fourth Semester

Paper Code: Theory (T) Practical (P)	Title	Theory	Practical	Total Marks
MSCNM-401T MSCNM-401P	Basics of PET/CT instrumentation & Medical Cyclotron/ Allied Instrumentation	75	40	115
MSCNM -402T MSCNM -402P	Nuclear Medicine Imaging (PET/CT)& Radionuclide Therapy	75	40	115
MSCNM -403	Recent advances in Nuclear Medicine	(SEMINARS/ INTERNAL ASSESSMENT)		70
MSCNM -404 MSCNM -404	**Dissertation and Grand Viva**	150	50	200
				Total = 500 Marks

M.SC. NUCLEAR MEDICINE SYLLABUS

FIRST YEAR - FIRST SEMESTER

PAPER I – (MSCNM101-T)

BASIC CONCEPTS OF HUMAN ANATOMY & CELL PHYSIOLOGY

(40 Lectures)

CELL ORGANIZATION AND CELL PHYSIOLOGY (18 lectures)

- **Cell as the basic structural unit**, Fine structure of prokaryotic and eukaryotic cell organization, cell organelles, cytoskeleton
- **Structure and function of cell membrane.** Types of transport across cell membrane, Mechanism of transport, Endoplasmic reticulum (ER), mitochondria, golgi complex, nucleus, lysosomes.
- **Cell cycle, events in cell cycle** – G1, S1, G2 phase, Control of cell cycle, Cell division, Cell transportation and malignant tumor growth. Cell aging and death, Apoptosis.
- **Cell adhesion, cell signalling**, concept of receptors, characterization and its function. Receptor – ligand interaction. Signal transduction
- **Energy requirements in cell metabolism,** high energy phosphate bond, Electron transfer phenomenon and biological transfer. Amino acids and proteins, carbohydrates, lipids, nucleic acids, vitamins and coenzymes, its mechanism, bioenergetics. Glycolytic and TCA cycles.
- **DNA structure**, Replication and Repair, RNA synthesis and Translation

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.
- **Axial skeleton**: Skull – cranium, face, air sinuses, vertebral column: regions, movements and vertebrae characteristics: sternum, ribs
- **Appendicular Skeleton**: bones involved – pectoral girdle, pelvic girdle, upper limb, lower limb. Joints, healing of bones, cellular activity,
- **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).

MICROANATOMY (4 lectures)

- **Epithelial tissue**: Electron microscopic structure and various structural modifications.
- **Connective tissue:** Structure, Characteristics, Function, Classification, Modified connective tissue (Blood, Lymph, Bone and Cartilage)

- **Muscle:** Structural and molecular organization of muscle and mechanism of muscle contraction.
- **Nervous tissue:** Structure of neuron, Function, Classification

PRACTICAL :– (MSCNM101-P)

1. To identify different parts of a human skeleton
2. To study the gross anatomy of organs viz. Lungs, Kidney, Heart, Brain, Liver, Spleen of the body with specimen
3. To identify types of epithelial tissue: (squamous, stratified, pseudostratified) using microscope.
4. To visualize micro anatomical view of cartilage system using light microscope.
5. To visualise microanatomical view of Respiratory system (Larynx, pharynx, trachea, principal bronchi, lungs) systems using light microscope.
6. To visualise microanatomical view of Digestive system (esophagus, stomach, small and large intestine, rectum) using light microscope
7. To visualise microanatomical view of Urinary system: Kidney, urethra, urinary bladder, using light microscope.
8. To visualise microanatomical view of Reproductive system of male: Testes, Ducts deferens, Seminal vesicle, prostrate using light microscope.
9. To visualise microanatomical view of Reproductive system of female: Ovary, fallopian tube, uterus using light microscope.
10. To visualise microanatomical view of Nervous system: neuron, neuroglia, gross anatomy of brain using light microscope.

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, 13th ed. (Elsevier). Guyton and Hall
2. Principles of Anatomy and Physiology, 15th ed. Tortora and Derrickson (Wiley).
3. Text Book of Human Histology with Colour Atlas, 7th 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 - FIRST SEMESTER

PAPER II – (MSCNM102-T)
HUMAN PHYSIOLOGY, IMMUNOLOGY AND CANCER BIOLOGY
(40 LECTURES)

HUMAN PHYSIOLOGY (20 lectures)

- **Endocrine system**: Brief description of endocrine organs, their hormones, functions of the hormones, diseases produced by excess or deficiency of the hormones. Feedback mechanisms. Special emphasis on Thyroid (Thyroid hormone production, hormonal control)
- **Circulatory system:** The heart as a pump, cardiac cycle, double circulation, heart sounds, ECG, methods of recording ECG
- **Respiratory system:** General physiological functions of respiratory system.
- **Nervous System:** Structure, function and organization of nervous system, signal transmission at synapses
- **Functions of Digestive system**: Brief study of different digestive juices and their functions
- **Urinary systems:** Physiology of urine formation
- **Reproductive system**: Oogenesis and ovulation in females, spermatogenesis in males.

IMMUNOLOGY (10 lectures)

- Innate and acquired immunity, cell mediated and humoral immunity, Primary & Secondary response curves, Antibody classification and their production, Structure of

Antibody, Monoclonal Antibody synthesis, Immunochemical assays (RIA, ELISA, IHC)

BIOLOGY OF CANCER (10 lectures)

- **Classification, nomenclature and definition of neoplasm.** 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
- Cancer biomarkers, histological alterations, Oncogenes and tumor suppressor genes, tumor progression

PRACTICAL :- MSCNM102-P

1. Study of Microscope
2. Study of Hemocytometer & diluting pipettes
3. To determine TLC count
4. To determine Total RBC count
5. To study differential leucocyte count
6. To detect apoptotic cells using TUNEL assay
7. To extract DNA from blood and tissue sample
8. Histological processing of tumor suppressor genes like p53, BCl2, Bax etc

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, 13th ed. (Elsevier). Guyton and Hall
2. Principles of Anatomy and Physiology, 15th ed. Tortora and Derrickson (Wiley).
3. Text Book of Human Histology with Colour Atlas, 7th ed. (Jaypee). Inderbir Singh
4. Biochemistry, 4th ed. (WH freeman and company). Lubert Stryer
5. The biology of cancer by Robert A Weinberg
6. Introduction to Cancer Biology by Momna Hejmadi

FIRST YEAR - FIRST SEMESTER

Paper III – (MSCNM103-T)

RADIATION PHYSICS

(40 Lectures)

NUCLEAR STRUCTURE AND RADIOACTIVE DECAY (16 lectures)

- **Nuclear structure** - atomic number, mass number, isotopes, isobars; Radioactivity - laws of radioactive decay, half-life, mean life, effective half-life. Types of radioactive disintegrations, specific activity, carrier-free radioactivity; Statistics of radioactive decay and propagation of statistical errors. Energy of ionizing radiation, electron capture.
- **Laws of successive transformations** - radioactive equilibrium: secular, transient and no-equilibrium. natural radioactive series, artificial radioactivity & production of radioisotopes, nuclear cross sections, elementary ideas about nuclear fission, fusion, reactors and neutron sources.
- **Characteristics of alpha, beta (electron, positron and electron capture) and gamma decay** and their spectra, internal-conversion, phenomenon of annihilation and pair production, positron emission, annihilation radiations, metastable state and isomeric transitions, X-rays: characteristic and continuous spectrum, auger effect.

RADIATION UNITS (4 lectures)

- **Units of radioactivity**: Becquerel, Curie, specific activity, carrier free activity, resonance absorption and Mossbauer Effect. 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.

INTERACTIONS OF NUCLEAR RADIATIONS (15 lectures)

- **Interaction of electromagnetic radiation with matter:** coherent scattering, photoelectric effect, Compton effect, pair production and relative importance of these processes. Attenuation of photon beams: attenuation, energy transfer and energy absorption - attenuation and mass energy absorption coefficients, half-value layer and X-ray filters.
- **Interaction of charged particles with matter:** directly and indirectly ionizing particles, elastic and in-elastic collisions, Energy loss of charged particles (electron and heavy charged particles) in medium, Stopping Power - Bethe Bloch Formula, Range energy relation - Bragg curve, Energy loss of electrons and positrons in matter-collision and radioactive loss, range energy relation - Continuous slowing down approximation (CSDA). Dependence of collision energy losses on the physical and chemical state of the absorber, empirical relations between range and energy, back scattering, Cherenkov radiation.
- **Interaction of neutrons with matter:** elastic scattering, energy transfer, logarithmic energy decrement, inelastic scattering, dependence on E and Z, neutron induced reactions - neutron capture, (n, p), (n, x), (n, y) etc. neutron activation.
- **Principle and working of X-ray tube**, application of filters; Microwave generator-Klystron and magnetron, Particle accelerators for industrial, medical and research applications, Cyclotron , Betatron, Linear Accelerator — Travelling and Standing Wave Acceleration. Details of accelerator facilities in India.

RADIO ACTIVITY AND ISOTOPES (5 lectures)

- **Radio activity – units- stability of nucleus** – N/P ratio, mass defect –binding energy – theory of nuclear disintegration – decay law, half life period –radioactive equilibrium. Radioactive series – nuclear reactions – nuclear reactions induced by P,N,D – nuclear fission – fusion – reactors.
- Production of radioisotopes: from nuclear reactors by (n, γ), Isotopes and their separation taking examples of Mo-99, I-131.

PRACTICAL :- (MSCNM103-P)

1. To measure Half Value Layer of β and γ emitters and determine linear mass absorption coefficients.
2. To study the factors producing background counts.
3. To study self absorption using beta emitting radioisotopes.
4. To study the back scatter of beta particle.
5. To determine absorption coefficients of biological tissues with β and γ radioactive sources of different energies.
6. To determine the half lives of radioactive isotopes
7. To study the change in activity of a sample consisting of two independently decaying radioisotopes.
8. To study the statistics of radioisotopic measurements and observe the effect of backround on the counting statistics.

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, 2nd ed. (Narosa Pbl. House) I. Kaplan
3. Nuclear Radiation Physics, 2nd ed. (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, 2nd ed. (Addison-Wesley) D.K. Cheng
7. Radiation Detectors and Instrumentation, 4th Edition (Wiley). Glenn F. Knoll
8. Techniques for Nuclear and Particle Physics experiments, 3rd Edition (Narosa). W.R. Leo
9. The Physics of Radiation Therapy, 5th ed. (Lippincott Williams and Wilkins). F.M. Khan
10. Medical Imaging Physics, 4th Edition (Wiley-Liss) W.R.Hendee & E.R.Ritenour
11. Radiation Detection and Measurement, 4th Edition, 2010, G. F. Knoll
12. Measurement and Detection of Radiation, 4th Edition, Nicholas Tsoulfanidis

FIRST YEAR - FIRST SEMESTER

Paper IV – (MSCNM104-T)
RADIATION BIOLOGY AND RADIATION CHEMISTRY
(40 lectures)

MOLECULAR AND CELLULAR RADIOBIOLOGY (12 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 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. Bystander Effect, Apoptotic and Mitotic death.
- Radiation effect on biomolecules: Radiation effects on proteins, nucleic acids, carbohydrates, lipids, polymerases, transferases, isomerases and anti-oxidative enzymes.
- Radiation and independent cell systems: target Theory, multitarget theory, target size, multihit theory, multitarget multihit theory. Cellular Injury and Dose reponse Models, Linear and Linear Quadratic model.
- Differential cell response: Criteria of radiosensitivity, 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 HUMAN BODY SYSTEM (12 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.
- Acute radiation effects: Lethality, acute radiation syndrome in mammals, effects of prenatal development, radiation effects on regeneration.
- Radiation Carcinogenesis. Deterministic and Stochastic effects. Repair of Radiation Damage. Effects of radiation on embryo and fetus.

MODIFICATION OF RADIATION RESPONSE (4 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.
- Radiation sensitizers and Radiation protectors.

RADIATION CHEMISTRY

BASIC CHEMISTRY (8 lectures)

- Various concepts of acids bases and buffers – ionic product of water – pH – determination of pH – hydrolysis constant – buffer solution –
- Ionic bonds – lattice energy of ionic compound – Born-Lande equation. Born-Haber cycle – covalent character of ionic bond . covalent bond –hybridization involving s,p,d and f orbitals – SP3, SP2, SP, dSP3,d2 SP3 hybridization. Co-ordination compounds

- Rates of reactions – factors influencing rates of reactions – order and molecularity – first, second and third order
- Influence of temperature on reaction rates – Arrhenius equation. Calculation of Arrhenius parameters.

BASIC RADIOPHARMACEUTICAL CHEMISTRY (4 lectures)

- Characteristics of an ideal radiopharmaceutical and quality control. Physicochemical techniques and its application in radio pharmacy: Chromatography, Electrophoresis and Spectroscopy.

PRACTICAL:- MSCNM104-P

1. Effect of pH on binding efficiency on protein sample
2. Effect of temperature on binding efficiency on protein sample
3. Effect of drug concentration on binding efficiency on protein sample
4. Effects of ionizing radiation DNA (fragmentation studies)
5. Chromosomal aberrations testing following ionizing radiation exposure
6. Lymphocyte extraction and counting following whole body x-irradiation

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. Radiobiology for the radiologists, 6th ed. by Eric J Hall
2. Physics and Radiology of Nuclear Medicine, 4th ed. by Gopal Saha
3. Introduction to radiation biology by B Uma Devi, Nagarathanam, Rao
4. Radiation Biology by Casarett

FIRST YEAR - SECOND SEMESTER

PAPER I – (MSCNM201-T)
RADIATION DETECTION & MEASUREMENTS
(40 Lectures)

RADIATION DETECTORS (2 lectures)

- Principle of radiation detection and types of detectors

GAS FILLED DETECTORS (3 lectures)

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

SCINTILLATION DETECTORS-ORGANIC AND INORGANIC SCINTILLATION DETECTORS (6 lectures)

- Scintillation detector principles- inorganic NaI (Tl), Bismuth germanate detector, barium Fluoride, and organic detectors light collection and mounting, yttrium orthosilicate detector; scintillation characteristics- light output, decay time. Features of gamma ray spectra - photo peaks, Compton valley, edge and plateau, backscatter peak, iodine escape peak, annihilation peak. Pulse height selector, energy resolution and calibration, geometric efficiency, intrinsic efficiency,

LIQUID SCINTILLATION COUNTERS (4 lectures)

- Composition of liquid scintillator (scintillation cocktail): primary solute, secondary, solute and organic solvent (toluene, 1, 4 dioxane, anthracene) and solubilizing agents

for tissues, coincidence circuits and display. Quenching and quench correction methods: Internal standard method, external standard method and channel ratio.

SEMICONDUCTOR DETECTORS (4 lectures)

- Semiconductors junction, surface barrier detectors, high purity germanium detectors, response and characteristics.
- Neutron detectors: Basic principles and applications.
- Well counter – Geometry factor, dual radionuclide counting.

COUNTING AND MEDICAL STATISTICS (6 lectures)

- Application to radiation detection-uncertainty calculation, error propagation, time distribution between background and sample, minimum detectable limit
- 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, statistical aspects of gamma ray and beta ray counting, statistical accuracy in double isotope technique.

WHOLE BODY COUNTING STUDIES (3 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.

GENERAL SYSTEMS FOR OPERATION AND DETECTION (12 lectures)

- Use of photographic emulsions stripping film technique, dipping method, grain density counting and track counting, X-ray films, intensifying screens, fluoroscopy.
- Physics of TLD, characteristics TLD phosphors, glow curves, dose and energy response, sensitivity and application in-dosimetry and personnel monitoring devices.
- OSLD Reader for medical and research applications, TLD Badge Reader, OSLD badge reader, Digital pocket dosimeter.
- Area monitoring instruments: Portable and fixed area monitors, beta-gamma zone monitor, Survey meters, wide range survey instrument, teletector,
- Contamination monitoring instruments: portable contamination monitor, hand and foot surface contamination monitor, portal monitor, laundry monitor, floor monitor
- Neutron monitoring instruments, REM counter
- Calibration of Radiation Protection Instruments: Fundamental concepts of instrument calibration, Basic requirements for calibration and various parameters checked during calibration.

PRACTICAL:- (MSCNM201-P)

1. To find out the spectrum of energies emitted by a radioisotope by using gamma ray – spectrometer.
2. Gamma ray spectrometry with a single channel analyzer.
3. To determine the plateau of GM tube and find out the dead time/ resolving time.
4. To determine the efficiency of GM counter and find out the strength of the unknown radioactive source
5. To determine the energy resolution of spectrometer and effect of scatter in source volume

6. To identify unknown radionuclide on the basis of its basis of its principal energy by using multi channel analyser

7. Effect of EHT and gain on spectrometer using a mixture of two radio nuclides

8. To learn the mode of operation of a scintillation counter and its operating characteristics

9. To determine the radiation response of thermo luminescent dosimeter (TLD)

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, 2nd ed. (Narosa Pbl. House) I. Kaplan
3. Nuclear Radiation Physics, 2nd ed. (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, 2nd ed. (Addison-Wesley) D.K. Cheng
7. Radiation Detectors and Instrumentation, 4th Edition (Wiley). Glenn F. Knoll
8. Techniques for Nuclear and Particle Physics experiments, 3rd Edition (Narosa). W.R. Leo
9. The Physics of Radiation Therapy, 5th ed. (Lippincott Williams and Wilkins). F.M. Khan
10. Medical Imaging Physics, 4th Edition (Wiley-Liss) W.R.Hendee & E.R.Ritenour
11. Radiation Detection and Measurement, 4th Edition, 2010, G. F. Knoll
12. Measurement and Detection of Radiation, 4th Edition, Nicholas Tsoulfanidis

FIRST YEAR - SECOND SEMESTER

PAPER II – MSCNM202-T
BASIC CONCEPTS OF ELECTRONICS, BIOMEDICAL INSTRUMENTATION AND TECHNIQUES
(40 Lectures)

SEMICONDUCTOR DEVICES (6 Lecturers)

- Theory of semiconductors: energy band (qualitative), intrinsic and extrinsic semiconductors, n-type and p-type semiconductors, majority and minority carriers. p-n junction properties forward and reversed bias, pnp and npn transistors and their characteristics.

DIGITAL CIRCUIT SYSTEM (4 Lectures)

- Boolean algebra and logic gates: OR, AND, NOT, NOR, NAND and EXOR gates. Analog to digital converter and digital to analog converters. Power supplies- Regulated power supplies.

INSTRUMENTS FOR COUNTING, GAMMA RAY SPECTROMETRY (5 lectures)

- Electronics of PM tubes, preamplifiers, amplifiers, pulse height analyzers, coincidence & anti coincidence circuits, TPHC, MCA, scalers and timers, high voltage supply in gamma ray spectrometry.

TRANSDUCERS (4 Lectures)

- Properties and the principle of transducers: Resistive transducer, thermoresistors, thermistors, Pontemetric transducers, magnetoresistive transducers and their

biomedical applications. Inductive transducers, single inducers, mutual inducers, capacitive transducer, biological capacitors.

ULTRASOUND (5 Lectures)

- Ultra sound generators, properties of ultrasound- waves and its propagation in biological tissues, Pulse echo techniques, cavitation phenomenon, Doppler principle, involvement in design of medical instruments- scan A, scan B. scan M, 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 LASERS, applications of LASER in medicine, adverse effects of LASER.

NUCLEAR MAGNETIC RESONANCE (4 Lectures)

- Quantum mechanical description, Bloach equations, experimental techniques- NMR spectrometer, cw NMR and FT NMR; NMR spectrum- chemical shift, longitudinal and transverse relaxation times; Basic principle of MRI.

ATOMIC ABSORPTION SPECTROPHOTOMETER (3 Lectures)

- Atomic Absorption spectroscopy, basic principle and working, applications in biomedicine

MASS SPECTROMETRY (3 Lectures)

- Principle and working of Mass Spectrometer, applications in biology and medicine.

ELECTROCARDIOGRAPHY (2 Lectures)

- Principle and working of electrocardiograph. Biomedical applications of electrocardiography

SEPARATION TECHNIQUES (4 Lectures)

- Principles and applications, chromatography, paper TLC techniques, centrifugation, electrophoresis, Ultraviolet– visible spectroscopy : Basic principle and applications

PRACTICAL :- MSCNM202-P

1. To demonstrate working of an ECG machine
2. To demonstrate working of various types of semi conductors
3. To demonstrate working of ultrasound waves in a biological tissue viz abdomen, renal, thyroid etc
4. To measure AC voltage signal and its frequency using an oscilloscope and to study NPN & PNP transistor and characteristic of multivibrator.
5. 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.
6. Two stage RC coupled amplifier - frequency response.
7. Construction of a voltage multiplier.
8. Characteristics of a regulated power pack.
9. OPAMP circuits - Inverting and non inverting amplifiers.
10. Integrator and differentiator circuit using OPAMP.

11. To demonstrate ECG in normal and treated animals.

12. To demonstrate electrical impedances in biological tissues

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 - SECOND SEMESTER

PAPER III – MSCNM-203-T

APPLIED MATHEMATICS, BIOSTATISTICS AND COMPUTER APPLICATIONS

(40 Lectures)

APPLIED MATHEMATICS

NUMERICAL METHODS: (3 lectures)

- 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.

DIFFERENTIAL CALCULUS: (3 lectures)

- Differentiation – Derivative of a function of a real variable, derivatives of circular and inverse circular function, hyperbolic and inverse hyperbolic functions, successive differentiation, Leibnitz theorem (statement without proof) and simple problems.

INTEGRATION: (2 lectures)

- Primitive, different methods of integration – integration by substitution and integration by parts, definite integrals and its properties, double integrals (simple cases only)

LINEAR ALGEBRA: (3 lectures)

- Definition of a matrix, adjoint and inverse of a square matrix, orthogonal matrix, rank of a matrix, elementary transformation of a matrix – reduction of a matrix to

normal and echelon forms. Determinant of square matrix of order n, its properties, multiplication of determinants.

VECTOR ANALYSIS: (3 lectures)

- Dot and cross product of vectors, products of three or more vectors, derivative of a vector with respect to scalar parameter, gradient of a scalar point function, solenoid and rotational vectors.

INTRODUCTION TO BIOSTATISTICS AND STATISTICAL TERMS (2 Lectures)

- Statistics – Biostatistics and Biometry- Descriptive and Inferential Biostatistics – Sample and test Biostatistics – Statistical Terms - Limitations of Statistical Methods – Aims of Biostatistics –Applications of Biostatistics.

COLLECTION OF DATA (2 Lectures)

- Census and Sampling Methods of Data Collection – Necessity of Sampling – Types of Sampling Methods Random or Probability Sampling – Nonrandom or Non Probability Sampling.

CLASSIFICATION OF DATA AND FREQUENCY DISTRIBUTION (2 Lectures)

- Data – Data collection – Data Processing – Data Summarization – Classification of Data – Methods of classification of Data – Differences Between Classification and Tabulation – Formation of Frequency Distribution.

PRESENTATION OF DATA TABULAR REPRESENTATION OF DATA – GRAPHIC REPRESENTATION OF DATA (2 Lectures)

- Line Diagram – Histogram – Frequency Polygon – Frequency Curve – Cumulative Frequency Curve or Ogive – Scatter or Dot Diagram – Bar Diagram – Pictogram – Cartogram.

MEASURES OF CENTRAL TENDENCY AND DISPERSION (2 Lectures)

- Average – Objectives of Averages - Characteristics of an Ideal Measure of Central Tendency – Types of Averages - Mean, Median, Mode – Meaning of Dispersion – Measures of Dispersion – Range, Standard Deviation – Coefficient of Variation, Standard Error.

CORRELATION AND REGRESSION (2 Lectures)

- Correlation – Types of Correlation – Measures of Simple Correlation – Rank Correlation. Regression – Simple Regression – Regression Equation – Regression Coefficients.

PROBABILITY (4 Lectures)

- Important Terms and Concepts – Sample point, Sample space, Trial and Event; Classical Definition of Probability. Frequency Definition of Probability –Rules of Probability (Addition Rule and Multiplication Rule) Random variable and Probability Distribution – Binomial Distribution, Poisson Distribution and Normal Distribution. 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

TEST OF HYPOTHESIS AND TESTS OF SIGNIFICANCE (3 Lectures)

- Statistical Inference, Test of Significance, Procedure for Carrying out test of Significance – Computation of Test of Significance – Test for the mean of a Normal Population.
- Sampling and sampling distributions, confidence intervals. Clinical study designs and clinical trials. Hypothesis testing and errors. Regression analysis.
- The basic idea of significance tests, Tests of hypothesis for the parameters of normal distribution (two sample problems also) including testing for population proportions. Confidence intervals for the parameters of normal distribution (two sample problems also).

CATEGORICAL DATA: (4 Lectures)

- Measurements scales, tests of associations, Chi-square test, Yate's correction. Sensitivity, Specificity, Predictive value and ROC curve, Analysis of variance (ANOVA), one way and two way classifications, Multi-variate analysis of variance (MANOVA).
- Non Parametric Statistics: Sign-test, Wilcoxon-signed rank test, Mann Whitnet U-statistic

SPSS/STATISTICAL in data analysis and graphics (3 Lectures)

PRACTICAL:- MSCNM203-P

1. To study structural and conformational characteristics of various bio-molecules using molecular modeling.
2. To demonstrate the use of various scientific languages like FORTRAN, C^{++} for scientific applications.
3. To study various DOS commands for scientific applications Demonstration of SPSS statistical software.
4. Demonstration of MATLAB software.
5. Demonstration in Excel and Power point.

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, 7th ed. (Marcel Dekker). Hoffman
2. 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

Let us C , Y. Kanetkar

FIRST YEAR - SECOND SEMESTER

PAPER IV – MSCNM204-T
RADIOISOTOPES APPLICATIONS & RADIATION SAFETY
(40 Lectures)

PRINCIPLES OF RADIATION SAFETY AND CONTROL (10 lectures)

- Concept of maximum permissible exposures, Internal and external radiation hazards, classification of radioisotope laboratories, safe transportation, decontamination procedures and waste disposal.

RADIONUCLIDES IN BIOLOGY (15 lectures)

- Concept of uptake of radionuclides in the organ of interest, effective half life/ biological half life in specific organs and whole body. ^{51}Cr labeling with red blood cells: applications in blood volume measurement, spleen uptake, red cell survival studies, red cell volume and proteins turn over Theoretical aspects of tracer techniques and basic requirements for radiotracer investigations.
- ^{32}P applications in polycythemia vera and leukemia
- ^{14}C applications in urea breath test, Radiorespirometry, in vitro uptake and turnover studies using ^{14}C glucose,
- ^{14}C amino acids and fatty acids.
- ^{3}H applications in autoradiography and metabolic studies.
- ^{59}Fe absorption studies, Techniques for studying absorption of labeled substance, ^{59}Fe turn over studies, plasma iron clearance

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

BIO-MEDICAL APPLICATIONS OF RADIONUCLIDES (15 lectures)

- Thyroid radioactive uptake measurements: Tracer dose, use of carrier, standard and phantom, shielding and collimation, factors affecting thyroidal radioactive iodine uptake,
- I-131, thyroid stimulation test, thyroid clearance rate thyroid suppression test, perchlorate discharge test, T3 charcoal test.
- ^{131}I therapy for treatment of hyperthyroidism and thyroid differentiated carcinoma.
- ^{125}I applications: General principle of radioimmunoassay (RIA), ^{125}I applications in radioimmunoassay of T3, T4, TSH and other hormones. Principle of immune radiometric assay (IRMA).
- ^{99m}Tc applications in medical imaging of different organs and dynamic /function studies.
- $^{201}Tl/^{82}Rb$ – myocardial uptake/perfusion imaging, ^{67}Ga for scintigraphy of tumors and infections,
- ^{18}FDG in brain, heart and tumor imaging
- Radionuclides in therapy: Applications of ^{89}Sr, ^{186}Re-HEDP, ^{153}Sm-EDTMP, lutetium-177 for treatment of different organ system disorders.

PRACTICAL:- MSCNM204-P

1. To determine the Rf of radiopharmaceuticasls using different solvents.
2. Use of gamma ray scintillation counter for measuring in vivo thyroid uptakes following administration of carrier-free ^{131}I.
3. To study the influence of carrier on in- vivo uptake carrier free ^{131}I by the thyroid.
4. To measure the blood volume using ^{99}Tc labeled red blood cells.
5. To prove that spleen is the storehouse of worn out red blood cells by using ^{51}Cr labeled red blood cells.
6. To find out the target / non target ratio of ^{99m}Tc labeled pharmaceuticals.
7. To determine the biological half life of $^{99m}Tc\ O_4^-$ and labeled pharmaceuticals.
8. To perform perchlorate discharge test

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, 7th 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 7th ed. (Springer). Gopal B. Saha
7. Physics and Radiobiology of Nuclear Medicine 4th ed. (Springer). Gopal B. Saha

SECOND YEAR - THIRD SEMESTER

PAPER I – MSCNM301-T
NUECLEAR MEDICINE INSTRUMATION
(40 Lectures)

GAMMA CAMERA (17 Lectures)

- Basic principles of gamma camera.
- Collimators - parallel hole, divergent, convergent pinhole, fan beam, slant hole collimator.
- 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.
- 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) (8 Lectures)

- Basic principles of 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. QC of SPECT/CT

PROBE SYSTEMS (4 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 (3 Lectures)

- Principles and its applications.
- QC of Dose calibrator

INSTRUMENTS IN RADIATION SAFETY (8 Lectures)

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

- 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

PRACTICALS (MSCNM-301P)

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. Line Spread Function
5. Phantom studies for scintigraphy
6. Determine the half life of a radionuclide with the help of a Dose Calibrator.
7. Evaluate the geometric/volumetric variation of the radioactivity using Dose Calibrator.
8. Determine the Intrinsic uniformity of Gamma Camera.
9. Determine the extrinsic uniformity of Gamma Camera for the given collimator.
10. Perform experiment to determine the spatial resolution and linearity of Gamma Camera.
11. Determine the COR of the Gamma Camera.
12. Devise an experiment to measure the Pixel size for 128X128 and 256X256 matrix size of the Gamma Camera.
13. Determine the Dead time by two sources method and determine count rate at 20 % count loss.
14. Determine the system sensitivity with different collimators.

15. Perform the total performance test on the SPECT gamma camera.

Books:

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

- Principles of Nuclear Medicine , 2nd ed — Henry N. Wagner (Jr.)
- Nuclear Medicine Technology and Techniques, 2nd ed — Bernier,Christian, Langan
- Principles & Practice of Nuclear Medicine , 2nd ed — Early & Sodee
- Basics of PET Imaging. 3rd ed — Gopal Saha
- Principles of Applied Biomedical Instrumentation, 3rd ed — Geddes, Baker
- Nuclear Medicine Instrumentation, 2nd ed — Cherry, Pheleps, Sorenson

SECOND YEAR - THIRD SEMESTER

PAPER II - (MSCNM-302T)
PRINCIPLES AND PRACTICE OF RADIOPHARMACY
(40 Lectures)

RADIONUCLIDE PRODUCTION AND CHARACTERISTICS (3 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.

RADIONUCLIDE GENERATORS (4 Lectures)

- SPECT and PET 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 ^{99}Mo/^{99m}Tc 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.

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.

SPECIFIC METHODS OF LABELING (6 Lectures)

- Methods of radiolabelling : isotope exchange reactions, introduction of foreign label, labeling with bi-functional chelating agents, biosynthesis, 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 ^{99m}Tc: ^{99m}Tc 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 (6 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: (5 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

(4 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 radiopharmaceuticals in different organs.

CHARACTERISTICS OF PET RADIOPHARMACEUTICALS (4 Lectures)

- Physical and chemical characteristics of Positron emitters.
- Synthesis of 18-FDG, $^{11}CO_2$, $^{13}NH_3$ and $H_2{}^{15}O$, Production of F-18 FDG and other F-18 Radiopharmaceuticals, ^{68}Ga labelled compounds.
- Recent trends in radiopharmaceuticals and search for novel SPECT and PET radiopharmaceuticals.
- Clinical applications of the radiopharmaceutical, quality control, pharmacokinetic data, radiation dose.

PRACTICAL: - MSCNM-302P

1. Demonstration of ^{99}Mo-^{99m}Tc column generator.
2. To separate ^{99m}Tc from ^{99}Mo and determine the efficiency of extraction.
3. Perform the quality control of elute from 99Mo-99mTc Generator.
4. Perform the Radiochemical Purity of the given radioparmaceutical, using Paper chromatography.
5. Prepare single vial kit preparation of radiopharmaceutical.
6. Prepare double vial kit preparation of radiopharmaceutical. Prepare ECD

7. Prepare triple vial kit preparation of radiopharmaceutical. Prepare the Sulphur colloid.
8. Prepare a radiopharmaceutical involving boiling step. Prepare Mebrofenin.
9. To prepare solid meal for GET study.

Books:

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

- Fundamentals of Nuclear Pharmacy, 7th ed. — Gopal Saha
- Radiopharmaceuticals — Gopal Subramaniam
- Text Book of Radiopharamcy, 4th ed. — Sampson

SECOND YEAR - THIRD SEMESTER

PAPER III - (MSCNM-303T)

RADIOLOGICAL PROTECTION, BASIC CONCEPTS & DOSIMETRY

(40 Lectures)

RADIATION QUANTITIES AND UNITS (6 Lectures)

- Activity (Becquerel & Curie), energy, exposure(C/kg & Roentgen)
- LET, charged particle equilibrium (CPE), mass attenuation coefficient, mass stopping power, air kerma, Terma,
- Absorbed dose (Gray & Rad), radiation weighting factors (WR), tissue weighting factors (WT), equivalent dose (Sievert & Rem), effective dose (Sievert & Rem), Collective Effective dose (Person Sv), Annual Limit of Intake {ALI} (Becquerel), Derived Air Concentration {DAC} (Becquerel/m^3), personnel dose equivalent, committed dose.

BASIC PRINCIPLES OF RADIATION DETECTION (8 Lectures)

- Bragg Gray cavity Theory, Interaction co-efficient, interaction cross section, fluance, mass energy transfer and absorption co-efficient.
- Gas filled detectors – Ionization chamber (Free air ionization chamber, Well type, Cylindrical, Parallel-Plate) – Theory and design – construction of thimble ionization chambers, gas multiplication – Proportional and GM counters & their characteristics, radiation absorbed dose measurement (standard calibration protocols).

- Alternate standard methods of dose measurements (Film, TLD, OSL, diodes, chemical dosimeters and Monte Carlo Simulation)

GENERAL PRINCIPLES OF RADIATION PROTECTION AND LIMITS (8 Lectures)

- Principles of radiation protection- time, distance and shielding, specific gamma ray constant (Γ) and method of calculation for essential isotopes. Radiation weighting factor, linear energy transfer (LET), Relative biological effectiveness (RBE), Quality factors, equivalent dose, effective dose, collective equivalent dose, total effective dose equivalent, REM, Sievert
- Natural radiation exposure, cosmic radiation, terrestrial radiation, nuclear fall outs and medical exposures, Basis for exposure limits, ALARA, Radiation dose limits- occupational exposures, members of the public, trainee, maximum permissible doses- (ICRP, AERB recommendations), exposure of embryo/fetus younger persons, risks associated with recommended limits.

RADIATION MEASURING & MONITORING INSTRUMENTS (8 Lectures)

- Film badges, film densitometers, TLD badge, Thermo luminescent dosimeter readers for medical applications –
- Calibration, dose calibrators, Digital pocket dosimeters using solid state devices, GM counters – Pan cake,

- Teletector and use of survey meters– Gamma area (Zone) alarm monitors – Contamination
- Monitors for alpha, beta and gamma radiation – Hand and Foot monitors, Air Monitors for radioactive particulates and Gases, Neutron Monitors. Details of commercially instruments and systems. Use of dose constraints for staff and pregnant women. ICRP and National radiation safety standards Instruments

TRANSPORTATION OF RADIOACTIVE SUBSTANCES (3 Lectures)

- Historical background, classification of radioactive materials,
- General packing requirements, transport documents, labeling and marking of packages, transport of large radioactive sources and fissile material, exemptions from regulations.

RADIOACTIVE DECONTAMINATION AND WASTE DISPOSAL (7 Lectures)

- Radioactive decontamination of labs, clothes, hands, glassware, gloves, metals, plastics, paints and bricks, decontamination of person, decontamination of room,
- General principles, administration/misadministration of radiopharmaceuticals, release of patients administered with radiopharmaceuticals.
- Origin and types of waste, classification of Radioactive waste, liquid, gaseous and solid waste,
- Storage, transport, disposal of all type of waste, disposal of animal carcasses and radioactive foliage, disposal limits for ground burial and sanitary sewage system, incineration, disposal of long-lived and indispersible radioactive wastes.

- Management of decaying radioactive source (sealed/unsealed sources) storage and transfer to authorized personal,

PRACTICALS: - MSCNM-303P

1. To determine the half-life of a radioactive material.
2. Radiation exposure measurement: effect of distance, Shielding and time.
3. Radiation absorbed dose calculations exercises
4. Study of energy dependence of a pocket dosimeter and a survey meter
5. Demonstration of transport of radioactive materials
6. Monitor the given item for contamination, if found contaminated, then perform the Decontamination using contamination monitor.
7. Perform the wipe test on the floor and determine the level of contamination on the floor.
8. Demonstration of TLD badges, Pocket dosimeters.
9. To perform Radiation survey around the cyclotron and Radio-iodine therapy Ward.
10. To calculate weighted CTDI (body and head) using ion chamber for QA testing of CT machine.

Books:

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

- Radiation Detection and Measurement, 4th Edition G. F. Knoll
- Measurement and Detection of Radiation, 4th Edition, 2015, Taylor and Francis
- Handbook of Health Physics and Radiological Health — Shleien, Slaback, Birkey

- Radiation Safety for unsealed Sources Pant GS
- 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

SECOND YEAR - THIRD SEMESTER

PAPER IV – (MSCNM-304T)

NUCLEAR MEDICINE IMAGING (SPECT/CT) AND NON-IMAGING TECHNIQUES (40 LECTURES),

DIAGNOSTIC IN-VIVO TECHNIQUES (28 lectures)

- **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
- **Cardiac study-** static blood pool imaging, Rest/stress Myocardial imaging, Infarct imaging, MUGA, Gated blood pool study, First pass study.
- **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, T3/T4 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.

- **Central nervous study-** cerebral blood flow dynamic studies, static brain imaging, cisternography and ventriculoatrial and ventriculoperitoneal shunts.
- **Miscellaneous studies-** Lacrimal scintigraphic imaging, Lymphatic imaging, Venography, adrenal imaging using ^{131}I-MIBG, Bone marrow imaging, Infection & Inflammation imaging, Tumour Imaging, ^{67}Ga imaging

IN-VIVO NON-IMAGING TECHNIQUES (12 Lectures)

- GFR plasma sample method,
- Radioiodine Thyroid uptake,
- RBC survival study,
- Splenic sequestration study,
- Estimation of blood volume, Red cell volume, plasma volume,
- Vitamin B12 absorption study Iron absorption study.

PRACTICAL:- MSCNM-304P

1. Drawing of blood from patients
2. Determination of blood glucose using glucometer
3. To perform Bone scan (3-phase, whole body and statics)
4. To perform MPI.
5. To perform Lung perfusion study
6. To perform Renogram study (using DTPA/EC)
7. To perform DMSA scan
8. To perform DRCG
9. To perform Gated Blood pool scintigraphy.
10. To perform Salivary scintigraphy
11. To perform Solid GET
12. To perform GER
13. To perform Liver scan using SC
14. To perform Hepatobillary study.
15. To perform Brain SPECT study
16. To perform adrenal imaging using iodine 131 MIBG
17. To perform thyroid scan
18. To perform parathyroid scan
19. To perform whole body Iodine-131 scan
20. To perform RAIU
21. To calculate GFR using plasma sample method

Books:

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

• Fundamentals of Nuclear Pharmacy, 7th ed. (Springer).	Gopal Saha
• Radiopharmaceuticals	Gopal Subramaniam
• Text Book of Radiopharamcy, 4th ed.	Sampson
• Radio immunoassay Principles & Practices	Pillai & Bhandarkar
• Nuclear Medicine in Vitro	B. Rothfield
• Principles of Nuclear Medicine, 2nd ed.	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

SECOND YEAR – FOURTH SEMESTER

Paper I - (MSCNM -401T)

Basics of PET/CT instrumentation & Medical Cyclotron

(40 Lectures)

PET AND COINCIDENCE DETECTION (13 Lectures)

- **Basic principles of PET imaging,** PET detector and scanner designs detectors – BGO, NaI (Tl), L(Y)SO; Time of Flight Attenuation correction with transmission sources – 68Ge, 137Cs. Techniques for image registration . Data corrections: normalization, uniformity correction, scatter correction, random correction.
- **Reconstruction techniques,** Filtered Back Projection, Iterative reconstruction: general principles, Maximum likelihood reconstruction, 2-D and 3-D reconstructions, performance characteristics of PET imagers.
- **Image Display**, Displaying PET images, Maximum Intensity Projection Images (MIPs), Quantification, from measured disintegration events to activity concentration. Performance characteristics, Kinetic modelling and Standardized Uptake Value (SUV)
- **Quality control of the PET/CT**Daily, weekly and monthly Quality control of the PET/CT.
- **PET v/s SPECT**, Dedicated and hybrid PET systems.

COMPUTED TOMOGRAPHY (3 Lectures)

- **Principles of Tomography**, longitudinal and transverse or axial tomography, multisection radiography. Principlesof CT, design of equipment, reconstruction of algorithms and various biomedical applications. CT QC.

MR/CT/ULTRASOUND IMAGING (4 Lectures)

- **Physics of magnetic resonance,** magnetic resonance imaging, MRI equipment and principle, its advantage overCT/ Ultrasound, functional magnetic resonance imaging, limitations and uses of MRI.

FUSION IMAGING (4 Lectures)

- **Definition, introduction**, Software and hardware fusion of imagesSPECT/ CT Fusion Imaging: Principles, applications, limitations and usesPET/CT Fusion Imaging: Principles, applications, limitations and uses.

PRE-CLINICAL 'SMALL-ANIMAL' PET SCANNERS (3 Lectures)

- **Use of CT, PET and SPECT** for imaging of small animals. Animal conditioning, dynamic studies and otherapplications of multimode PET+SPECT+ CT.

TELEMEDICINE (3 Lectures)

- **Newer Computer applications in Nuclear Medicine** - Medical Data Communications and Computer Networks.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 inMTLAB® and Mathematica® software packages.

MEDICAL CYCLOTRON (10 Lectures)

- **Basic working principles and instrumentation of cyclotron**, type of cyclotron, cyclotron generated radionuclides, cyclotron shielding, neutron detection and other quality control procedures. Medical Cyclotron Principles and Working
- **Production** of F-18, C-11, N-13, O-15,

PRACTICAL: MSCNM -401P

1. Perform experiment to calibrate PET/CT
2. Demonstration of Cyclotron
3. Perform preconditioning of cyclotron
4. Perform beam targeting experiment in cyclotron
5. Perform synthesis of 18-F FDG
6. Demonstration of methods of acquisition of PET/CT procedures in cardiology, Neurology and Oncology.
7. Demonstration of SPECT/ CT Fusion Imaging principles.
8. Demonstration of PET/CT Fusion Imaging principles.

Books:

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

- Basics of PET Imaging, 2nd ed. — Gopal Saha
- PET and PET/CT in Oncology — Pehr, Biersack, Coleman
- Nuclear & PET Techniques, 5th ed. — Christian
- The essential Physics of Medical Imaging — Bushberg, Seibert, Leidholdt

SECOND YEAR- FOURTH SEMESTER

PAPER II (MSCNM -402T)

NUCLEAR MEDICINE IMAGING (PET/CT) & RADIONUCLIDE THERAPY

(40 Lectures)

BASIC MOLECULAR IMAGING (10 Lectures)

- **PET in the clinical setting**: Kinetic modelling and Standardized Uptake Value (SUV), Staging and use of PET in staging, Recurrence/re-staging, Monitoring response to therapy, Early response assessment, Radiotherapy planning, Advances in imaging techniques & image processing including fusion techniques.
- Need for image fusion in clinical imaging PET and SPECT, Clinical need for PET/CT and SPECT/CT, FDG - PET imaging in different tumor types, Clinical PET/CT - Other applications, Cardiac applications, Neurology applications, Infection and inflammation imaging, image guiding for radiotherapy & stereotactic surgeries.

PET STUDIES (7 Lectures)

- **Methods of performing PET/CT procedures** in cardiology, Neurology and Oncology, Gated PET/CT studies (respiratory and cardiac gating). Use of 18FDG and NH3 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

THERAPEUTIC APPLICATIONS OF RADIONUCLIDES (23 Lectures)

- **General precaution regarding contamination and radiation dosage** Pre and post therapy imaging and patient preparation.

- **Radio iodine therapy for Thyrotoxicosis:** Dosage administration - Precaution to be followed.
- Radio iodine therapy for Thyroid malignancy: Dosage administration - Precaution and care of patient.
- **Iodine131 - MIBG Indications** - Dosage - Administration - Precaution to be taken during administration.
- Treatment of bone pain: use of 32P-orthophosphate, 89Sr- Strontium chloride, 186Re-HEDP, 153Sm-EDTMP, 177Lu etc.
- **Radiation Synovectomy:** Intra articular TherapyIntravascular particulate radio nuclide therapy for HCC, liver metsLabeled receptor, peptides (Lu-177 DOTATATE/PSMA therapy)
- **Radioimmunotherapy:** Labeled Monoclonal antibodies
- Radiolabeled skin patches.
- Treatment of polycythemia Vera and leukemia.
- Treatment of malignant effusion in pleural and peritoneal cavities
- Advances in Radionuclide Therapy.

PRACTICAL: PAPER II (MSCNM -402P)

1. To set a protocol for PET imaging for Oncology patient
2. To set a protocol for PET imaging for cardiac viability study
3. To perform an Iodine-131 whole body survey scan
4. To demonstrate Iodine-131 therapy in a thyroid cancer patient
5. To demonstrate monitoring and discharge from the ward of a high dose Iodine 131 patient
6. To demonstrate and monitor iodine therapy for thyrotoxicosis

Books:

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

- Principles of Nuclear Medicine — Henry N. Wagner (Jr.)
- Nuclear Medicine Technology and Techniques, 4th ed. — Bernier,Christian, Langan
- Principles & Practice of Nuclear Medicine, 2nd ed. — Early & Sodee
- Basics of PET Imaging, 2nd ed. — Gopal Saha
- PET and PET/CT in Oncology — Pehr, Biersack, Coleman
- Nuclear & PET Techniques, 5th ed. — Christian
- Physics in Nuclear Medicine, 4th ed. — Cherry, Sorenson, Phelps

SECOND YEAR – FOURTH SEMESTER

(MSCNM -403)

RECENT ADVANCES IN NUCLEAR MEDICINE (Seminars/ Internal Assessment)

SECOND YEAR – FOURTH SEMESTER

PAPER IV – DISSERTATION AND GRAND VIVA

- DISSERTATION-150 MARKS
- GRAND VIVA-50 MARKS