

NAGALAND UNIVERSITY
Regulation and Syllabus For
Bachelor of Science in Nuclear Medicine Technology (B.Sc. NMT)
(ADOPTED FROM NCAHP SYLLABUS)
(3+1 years) Degree Course

2026

BACKGROUND OF THE PROFESSION

The Profession of Nuclear Medicine Technologists, and Radiochemist forms an indispensable cornerstone of modern healthcare.

Nuclear Medicine Technologists are pivotal in acquiring functional and metabolic images, offering unique insights into disease processes often invisible to anatomical scans. Their direct patient interaction, coupled with their commitment to radiation safety, ensures both diagnostic efficacy and patient well-being.

Nuclear Medicine Technologists are the guardians of safe and effective radiation use, meticulously calibrating equipment and establishing stringent safety protocols. Their expertise in image reconstruction and data analysis enhances the diagnostic precision of nuclear medicine procedures.

Radiochemists are the innovative chemists who design and synthesize the essence of nuclear medicine – the radiopharmaceuticals. Their work in developing targeted molecular imaging agents and theranostic tools is revolutionizing disease detection and treatment. They ensure the quality and purity of these radioactive drugs, a critical aspect of patient safety and procedural reliability.

The collaborative synergy between these three professions is vital for translating the power of nuclear science into tangible benefits for patients. Together, they enable early and accurate disease diagnosis, personalized treatment strategies, and continuous medical imaging and therapy advancements. Their combined expertise spans a vast spectrum, from the initial creation of radioactive tracers to their safe administration and the interpretation of the resulting images. This multidisciplinary approach allows for a comprehensive understanding of disease at a molecular level, leading to more informed clinical decisions. The importance of these professions is underscored by their contribution to diverse medical fields, including oncology, cardiology, neurology, and endocrinology. As medical technology continues to evolve, the specialized knowledge and skills of Nuclear Medicine Technologists, and Radiochemists will remain crucial for pushing the boundaries of diagnostic and therapeutic medicine, ultimately improving patient outcomes and quality of life.

SCOPE OF PRACTICE

Nuclear Medicine Technologist Professionals possess, utilize, and maintain radiation protection and safety knowledge. They thoroughly understand the body's structure, how it can be affected by injury, and the causes and effects of disease when taking a Gamma Camera / PET scan. Their work does include a wide range of different imaging modalities, like Gamma camera, SPECT, SPECT-CT, PET-CT, PET-MR, Radiochemistry Lab, Radiation Safety, and Decontamination of facilities and Medical Cyclotron. Nuclear Medicine Professionals are the primary liaison between patients, Nuclear Medicine Physicians and other support team members. They remain sensitive to patient needs through good communication, assessment, monitoring, and care skills. As members of the health care team, diagnostic Nuclear Medicine Technologists in Nuclear Medicine participate in quality improvement processes and continually assess their professional performance. They engage in continuing education to include their area of practice to enhance patient care, public education, knowledge and technical competence.

SPECIFIC ROLES WITH DESIGNATIONS

Nuclear Medicine Technologist:

- Their scope encompasses preparing and dispensing radiopharmaceuticals, operating imaging equipment (gamma cameras, PET/CT), and ensuring patient safety and comfort during procedures.
- They review patient history, explain procedures to the patients, and monitor patients for adverse reactions.
- Technologists perform routine quality control on imaging and non-imaging equipment, acquire and process static and dynamic images, and participate in radiation safety protocols, adhering to regulations and institutional policies.
- They may also perform in vitro tests and assist in therapeutic procedures under authorized user supervision.
- Their practice demands technical expertise, patient care skills, and a strong understanding of radiation safety related to radiopharmaceuticals and patients.
- Their scope involves ensuring the safe and effective use of radiation, managing quality control of imaging equipment, and optimizing image acquisition and processing techniques.

- They calculate radiation doses pertaining to the Internal Dosimetry of the unsealed radionuclides/radiopharmaceuticals
- They establish safety protocols and ensure regulatory compliance.
- Nuclear Medicine Technologists are crucial in acceptance testing and commissioning new equipment, and troubleshooting technical issues.
- They play vital role in developing advanced imaging and analysis methods for newer/emerging radiopharmaceuticals.
- They often train other staff and contribute to research and development in the field.
- Their expertise bridges physics principles with clinical applications in nuclear medicine.

Radiochemist:

- Their scope centers on the design, synthesis, quality control, and distribution of radiopharmaceuticals. They develop new radioactive tracers for diagnostic imaging and therapeutic applications, often targeting specific molecular pathways.
- Radio-chemist manage radiopharmaceutical production facilities, ensuring compliance with stringent regulatory standards for purity, stability, and sterility.
- Their work requires a deep understanding of chemistry, radiochemistry principles, and safety protocols for handling radioactive materials.

Nuclear Medicine Professionals use a range of imaging and non-imaging technology:

- **Gamma Camera:** Gamma camera imaging (Scintigraphy), is a nuclear medicine technique that uses a specialized camera to detect gamma rays emitted from radioactive tracer materials (radiopharmaceuticals) that have been administered to a patient. This allows for the visualization and assessment of the functional status of various organs and tissues within the body.
- **PET-CT Scanner:** PET-CT imaging is an advanced medical imaging technique that combines the functional information from a positron emission tomography scan with the detailed anatomical information from a computed tomography scan into a single, comprehensive examination.
- **PET-MR Scanner:** PET-MR imaging is a cutting-edge hybrid imaging technique that simultaneously combines the functional and metabolic information provided by positron emission tomography with the high-resolution anatomical and soft tissue detail offered by magnetic resonance imaging (MRI).
- **Medical Cyclotron:** A medical cyclotron is a type of particle accelerator used in healthcare to produce radioactive isotopes (radioisotopes) for medical imaging and therapy. It works by

accelerating charged particles, typically protons or deuterons, to high energies using magnetic and electric fields. These high energy particles are then directed to bombard a target material, inducing nuclear reactions that transform stable isotopes within the target into radioactive ones.

- **High Dose Therapy Facility:** High Dose Radionuclide Therapy or High Dose Radioisotope Therapy utilizes radioactive materials administered internally to deliver high doses of radiation directly to cancer cells or specific target tissues. This approach aims to maximize the therapeutic effect while minimizing damage to surrounding healthy tissues.

- **Low Dose Radionuclide Therapy:** Low Dose Radionuclide Therapy utilizes small amounts of radioactive materials, administered internally, to achieve therapeutic effects without the high levels of radiation associated with high dose therapies. The primary uses often revolve around modulating biological processes rather than direct cell killing in the same aggressive manner.

Course duration

It is recommended that any program developed from this curriculum should have a minimum duration of the following to qualify as an entry-level professional in Nuclear Medicine.

- **Bachelor's degree level:** Four-year program (including 1 year of clinical training /internship)

A Bachelor's degree program will have a minimum of one year devoted to clinical practice and on a continuum of rotation from theory to practice over the program. The 4-year degree program aims to develop the Nuclear Medicine technologist as a key multidisciplinary team member and enable them to execute advanced preparation/ planning/delivery, and quality assurance. The emphasis during the initial year should be on the academic content, establishing a strong scientific basis and engagement with the course principles. During the second and third years of training, emphasis should be laid on the process to refine the acquired theoretical knowledge and its application to clinical/reflective practice.

FUTURE ASPECTS:

With the change in disease dynamics and a multifold increase in the cases needing diagnostic medical imaging and evaluation, a well-structured postgraduate education program must also be encouraged to enhance research capacity within the country and widen the scope of clinical practice for the profession. Thus, a master's degree program with at least two years of education in a specialized Medical Nuclear Medicine field is recommended followed by at least one year of residency. The postgraduate students can contribute significantly to research and academics.

- **Master's degree level:** Three-year program (including 1 year of clinical training/ internship/ Residency)

A **Ph.D.** also plays a significant role in the academic system, research, and innovation.

However, for the award of Ph.D. Degree in Nuclear Medicine or in the relevant special fields, UGC Guidelines are to be followed for Ph.D. program.

Job availability

The job availability for Nuclear Medicine Professionals appears stable, with positive overall employment projections and consistent openings due to retirements and career changes. Opportunities exist in hospitals, outpatient imaging centers, research institutions, and industry roles and in abroad too.

Certification is increasingly important for employment.

The job market for Nuclear Medicine Technologists seems promising, with numerous openings listed across various institutions, including hospitals and universities. Their specialized radiation safety, equipment management, and image optimization skills are in demand. Advanced degrees and board certification are typically required. Radiochemist, crucial for developing and producing

radiopharmaceuticals, also have good job prospects, particularly in pharmaceutical companies, research institutions, and hospitals with nuclear medicine programs. Advanced degrees, especially a Ph.D., are generally necessary, along with expertise in radiopharmaceutical chemistry and regulatory compliance. Advancements in molecular imaging and targeted therapies drive the field.

Job opportunities for nuclear medicine technologists in India are gradually increasing, especially in metropolitan cities and advanced healthcare centers. With the rise in diagnostic imaging and cancer treatment facilities, demand for trained professionals is growing. Expanding private healthcare and research institutions are key drivers of future growth.

Nuclear Medicine Technology provides a service for multiple departments within the hospital, including emergency, outpatients, operating theatres and wards. Therefore, close liaison and collaboration with various other health care professionals are vital. After completion of this curriculum, broadly a nuclear medicine technologist gets opportunities to work at various health care institutes, as per their educational qualifications, under the following designations:

- Quality Control Professionals
- Quality Control Manager [Nuclear Medicine Technologist or Radiochemist]
- Medical Cyclotron Operator (with mandate training and certification)
- Radiochemist
- Radiological Safety Officer (Nuclear Medicine/ Medical Cyclotron Facility/ Radiopharmaceuticals Lab/Radionuclide therapy Facility/others)
- Nuclear Medicine Technologist
- PET-CT Technologist
- PET-MR Technologist
- PET-LINAC Technologist
- Radionuclide Therapy Technologist
- Applications Specialist
- Radiological Safety Officer
- Technical Manager
- Sales and marketing in the radiological industry
- Facility Manager
- Other Administrative posts in the medical imaging department and hospitals.
- Teaching and research faculty in medical and allied health science colleges

- Research Scientists in the medical imaging industry

Regulations for the Allied Health Sciences Bachelor Programs of the Nagaland University

The Regulations & syllabus are subject to modifications by the University from time to time.

1. Eligibility for Admission:

- (i) The candidate should have passed the Higher Secondary (10+2) from CBSE or State Education Board or any Govt. recognized Board with at least 50% marks for general candidates (UR) and 45% for SC/ST/OBC/NCL candidates in Physics, Chemistry, and Biology.
- (ii) The candidate should have attained the minimum age of 17 years during the admission.
- (iii) As per the Eligibility criteria described in National Commission for Allied and Healthcare Professions (NCAHP) Competency Based Curriculum for Nuclear Medicine Technology, candidate can take admission on disability quota for BNM program.
- (iv) **Lateral Entry:**
Candidates who have completed a two-year diploma programme in the concerned subject from Boards recognized by Central / State Government(s) / State / Central University with at least 50% marks in aggregate for (UR) candidates and 45% marks in aggregate for SC / ST / OBC / NCL candidates shall be eligible for Lateral Entry to the second year (3rd Semester) of Bachelor Programme in Allied Health Sciences.

2. Duration of the Course:

4 years, i.e., 3 years or 6 semesters of academic studies and one year of internship (B.Sc. NMT).

3. Medium of Instruction:

The medium of instruction for all the Allied Health Sciences courses shall be English.

4. Working Days Per Semester:

Each Semester consists of 90 working days, with eight hours of work per day and 40 hours per week, totaling 720 hours per Semester.

5. Internship Hours:

One-year Internship programs will include 1440 hours of practical training.

6. Attendance:

- (i) A candidate must secure a minimum of 80% attendance in theory classes. Students who fail to meet the requirement due to illness may be eligible for a 5% condonation, provided they submit a medical certificate from a registered medical practitioner.
- (ii) 100% in skills training (practical/internship) to qualify for the award of degree. In case of insufficient attendance, the candidate's internship period will be extended accordingly. There are no other exceptions to these rules under any circumstances.

7. Submission of Log Books:

- a. Every candidate shall maintain a log book and record his/her participation in the training programs conducted by the department.
- b. The practical record shall be evaluated by the concerned Head of the Department (Internal Evaluator) and the practical record marks shall be submitted to the University 15 days prior to the commencement of the theory Examinations.
- c. At the time of the practical examination, each candidate shall submit to the examiners his / her Log book duly certified by the Head of the Department as a bonafide record of the work done by the candidate.
- d. In respect of failed candidates, the marks awarded for record at previous examination will be carried over for the subsequent examination. The candidates have the option to improve his performance by submission of fresh records.

8. Revaluation / Scrutiny of Answer Papers:

- (i) There is no provision for candidates to request for revaluation of the answer papers of failed candidates in any examination. However, the failed candidates can apply for scrutiny.
- (ii) Nagaland University shall constitute a Result Moderation Committee of 3 members.

9. Pattern of Question Paper for University Examination:

Descriptive type Questions	= 30%
Descriptive Short Notes	= 30%
Short Answer questions	= 20%
MCQ Type	= 20%

10. Assessment:

- (i) Assessment for theory and practical examinations: - Students must attain at least 50% marks in each theory and practical component, both in internal assessments and in the final University examinations to pass the course. The final marks will be 75% from the University examination and 25% will be from the internal assessment.
- (ii) The distribution of marks between theory and practical shall be provided in the **Curriculum and Syllabi** of each course.
- (iii) Assessment for internship: - During the internship, students gain clinical experience and learn to document patient care effectively. Each student must maintain a logbook and a portfolio.

Activity	Marks %	Assessor
Log book	20	Supervisor
Portfolio*	20	Supervisor
Practical	40	Examiners
Viva voce	20	Examiners

*The portfolio provides one with an opportunity to demonstrate the breadth and depth of your knowledge on certain topics

The portfolio incorporates the follow documents:

- Curriculum vitae
- Progress reports
- “Summary of Competency Achievement” demonstrating the level of competency achieved in each sub-module.
- Samples of work prepared by the intern from at least 5 of the modules of internship training guide. A presentation delivered covering key aspects of the module.
- The clinical supervisor will examine the portfolio at regular (at least once in three months) intervals and provide feedback to the Intern.

(iv) Mode of Evaluation: -

Evaluation for Theory papers during Odd End Semester Examination shall be internally done by the colleges and Theory papers during Even End Semester Examinations shall be externally evaluated or as notified by the University.

Assessment methods

Traditional assessment of students consists of the yearly system of assessments. In most institutions, assessments consist of internal and external assessments, and a theory examination at the end of the year or semester. This assesses knowledge instead of assessing skills or competencies. In competency-based training, the evaluation of the students is based on the performance of the skills as per their competencies. Hence, all three attributes – knowledge, skills, and attitudes – are assessed as required for the particular competency. Several new methods and tools are now readily accessible, the use of which requires special training. Some of these are given below:

- Objective Structured Clinical Examination (OSCE), Objective Structured Practical Examination (OSPE), Objective Structured Long Examination Record(OSLER)
- Mini Case Evaluation Exercise (CEX)
- Case-based discussion (CBD)
- Direct observation of procedures (DOPS)
- Portfolio
- Multi-source feedback
- Patient satisfaction questionnaire

11. Internship Project:

As part of the internship, students are required to choose a relevant subject and prepare an in-depth project report, which should include the objective, scope of the project, and a detailed report.

12. Advancement to the Next Semester:

Advancement to the next semester is contingent upon meeting the following conditions and clearing any backlogs as described.

A student may not fail in more than two papers in the preceding semester to be eligible to advance to the next semester.

13. Repeat examination for failed candidates:

Failed papers in odd semesters can be repeated during the exams of the subsequent odd semester. Similarly, failed papers in even semesters exams can be repeated during the subsequent even semester exams.

14. Vacation:

Maximum of 15 days including Saturdays and Sundays

15. Re-Admission after Break of Study:

Students shall be allowed to continue after a break in study provided the maximum duration as given in Clause- 2 (ii) is not exceeded.

16. Award of the Degree:

- a. Candidates who have passed all written examinations and successfully completed the compulsory internship as per the university's requirements will be awarded the degree.
- b. Final Consolidated Mark sheet shall be issued by the Nagaland University to the candidate after submission of his/her Internship Completion Certificate by the College.

17. Academic Calendar:

- a. Odd semester shall be from July to December, and Even semester shall be from January to June.
- b. The odd semester and even semester university (end) examinations shall be conducted in the months of December and June respectively.

Credit Distribution

- Each semester would consist minimum of 20 credits.
- The credit distribution hours for Lecture, Tutorial, Practical, and Clinics are as follows:
 - Lecture / Tutorial: 1 credit = 15 hours
 - Practical: 1 credit = 30 hours
 - Clinical: 1 credit = 45 hours
- A semester has courses structured as theory, practical, laboratory and clinics. Each course is of minimum 2 credits.
- Internship duration is as per the course regulation.
- Abbreviations / Symbols used in the credit distribution table:
 - L - Lectures,
 - T - Tutorials,
 - P -Practical,
 - CL - Clinics,

- C - Total credits,
- IAC - Internal assessment component,
- ESE - End-Semester Exam,

Weightage for Internal Assessment Component (IAC) and End Semester Exam (ESE)

- The IAC component weightage for theory & practical is:
 - 50% from Mid-semester examination
 - 50% through Continuous assessment
- The ESE component weightage for theory & practical is:
 - 100% from end semester examination

Attendance

Minimum attendance requirements for each course is: Theory: 75 %

- Clinics / Practical: 80 %
- If attendance is less than prescribed the institute/university shall act as per its policy.

Evaluation / Examination

- The final evaluation for each course shall be based on Internal Assessment Component (IAC) and the End-semester examination (ESE) as per the weightage indicated for respective courses.
- Internal Assessment Component (IAC) shall be estimated based on the performance of the student in mid semester exam or sessional exam/s, and continuous assessment (class participation, assignments, seminars or any other component as applicable to a course)
- At the end of each semester, a regular End Semester Examination (ESE) for the odd and even semesters will be conducted in November-December/ May-June cycle respectively.
- A one week of preparatory leave will be given to students before they appear for the regular end semester examination.
- A student should obtain minimum of 40% Internal Assessment Component (IA) to be eligible for End Semester Examination. Failure to secure 40%, he/she will be not appearing for the regular End Semester Examination (ESE). However, the conduct of a supplementary examination shall be subject to the university/institute guidelines.

Minimum Requirements for Pass

Letter Grade	A+	A	B	C	D	E	F/I/DT
Grade points	10	9	8	7	6	5	0

• A ten (10) point grading system (credit value) is used for awarding a letter grade in each course.

DT – Detained/Attendance shortage, I – Incomplete

• A pass in a ESE will be reflected as grades. Candidate shall be declared to have passed in any course, when he/she obtains not less than **“E” grade**.

• However, when a student appears for a supplementary examination, the grade shall be awarded as per the university norms. In the absence of specific norms, the maximum grade that may be awarded shall be “C” grade or below, irrespective of the student’s performance.

• **Pass criteria for courses with End Semester Examination:** For theory / practical course, a candidate should secure a minimum of 40% in ESE and an overall 50% including IAC to be declared as pass.

• **Pass criteria for courses with Internal Assessment Component:** The students should obtain 50% IAC to be declared as pass in a given semester.

Calculation of GPA and CGPA

• Evaluation and Grading (**Relative Grading**) of students shall be based on GPA (Grade Point Average) & CGPA (Cumulative Grade Point Average).

• The overall performance of a student in each semester is indicated by the Grade Point Average (GPA). The overall performance of the student for the entire program is indicated by the Cumulative Grade Point Average (CGPA).

• A ten (10) point grading system (**credit value**) is used for awarding a letter grade in each course.

Letter Grade	A+	A	B	C	D	E	F/I/DT
Grade points	10	9	8	7	6	5	0

DT – Detained/Attendance shortage, I – Incomplete

Calculation of GPA & CGPA: An example is provided

Course Code	Course	Credit (a)	Grade obtained by the student	Credit Value (b)	Grade Points (a*b)
AHS 101	Course-1	4	B	8	32
AHS 103	Course-2	4	B	8	32
AHS 105	Course-3	3	A+	10	30
AHS 107	Course-4	4	C	7	28
AHS 109	Course-5	5	A	9	45
TOTAL		20	-	-	167

$$\text{1st Semester GPA} = \text{Total grade points} / \text{total credits}$$
$$167/20 = \mathbf{8.35}$$

Suppose in **2nd semester GPA = 7** with respective course credit 25

$$\text{Then 1st Year CGPA} = \frac{(8.35 \times 20) + (7 \times 25)}{20 + 25}$$
$$= 7.6$$

Program Exit / Probation Criteria

The candidate must complete all the course work requirements and credits by a **maximum of double the program duration** i.e., 8 years.

Semester Break

Students will have a semester break following their odd and even end- semester examinations as per the academic calendar.

Internship

- Internship will be for a duration of 1 year as per the program regulation. All students shall be paid stipend during their internship as decided by the respective State Allied and Healthcare Council.
- The intern should abide by the rules and regulations of the organization during the period of internship.
- An internship certificate with details of activities (including externship), clinical /relevant areas of postings with hours and research project will be issued to a candidate on completion of the Internship. The certificate must be authenticated by the HOD/Coordinator and HOI.
- Degree is awarded **only on** successful completion of internship.

Bachelor of Science in Nuclear Medicine Technology (BSc. NMT)
Semester Wise Distribution of Subjects

B.Sc. NMT SEMESTER I

Course Code	Course Title	Credit Distribution (L,T,P,CL area hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
BNM 1101	Basics of Biochemistry and Cell Biology	3	1	0	0	4	50	50	100
BNM 1102	Human Anatomy and Physiology for Nuclear Medicine	4	0	0	0	4	50	50	100
BNM 1103	Solid state physics and Electronics in Nuclear Medicine	3	1	0	0	4	50	50	100
BNM 1104	Fundamentals of Chemistry	2	1	0	0	3	50	50	100
BNM 1105	Mathematics in Nuclear medicine	2	1	0	0	3	50	50	100
BNM 1106	Practicum - I	0	0	4	0	2	50	50	100
Total		14	4	4	0	20	300	300	600

B.Sc. NMT SEMESTER II

Course Code	Course Title	Credit Distribution (L,T,P,CL area hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
BNM 1201	Introduction to Nuclear Medicine, Medical ethics and Patient care	2	1	0	0	3	50	50	100
BNM 1202	Applied chemistry: Organic Chemistry & Inorganic chemistry for Nuclear Medicine	3	1	0	0	4	50	50	100
BNM 1203	Radiation Physics	3	1	0	0	4	50	50	100
BNM 1204	Fundamentals of Electromagnetism in Nuclear Medicine	2	1	0	0	3	50	50	100
BNM 1205	Practicum - II	0	1	6	0	4	50	50	100
BNM 1206	Clinical Practice - I	0	0	0	6	2	50	50	100
Total		10	5	6	6	20	300	300	600

B.Sc. NMT SEMESTER III

Course Code	Course Title	Credit Distribution (L,T,P,CL area hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
BNM 2301	Fundamentals of Immunology and Microbiology	2	1	0	0	3	50	50	100
BNM 2302	Introduction to Radio pharmacy	3	1	0	0	4	50	50	100
BNM 2303	Nuclear Medicine Instrumentation on Physics	3	1	0	0	4	50	50	100
BNM 2304	Principles of wave and optical physics in biomedical imaging	2	1	0	0	3	50	50	100
BNM 2305	Practicum - III	0	0	6	0	3	50	50	100
BNM 2306	Clinical Practice - II	0	1	0	6	3	50	50	100
Total		10	5	6	6	20	300	300	600

B.Sc. NMT SEMESTER IV

Course Code	Course Title	Credit Distribution (L,T,P,CL area hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
BNM 2401	Radiochemistry	3	1	0	0	4	50	50	100
BNM 2402	Radiobiology	2	1	0	0	3	50	50	100
BNM 2403	Biostatistics	2	1	0	0	3	50	50	100
BNM 2404	Health Physics & Radiation Safety	2	1	0	0	4	50	50	100
BNM 2405	Practicum - IV	0	1	4	0	3	50	50	100
BNM 2406	Clinical Practice - III	0	0	0	9	3	50	50	100
Total		10	5	4	9	20	300	300	600

B.Sc. NMT SEMESTER V

Course Code	Course Title	Credit Distribution (L,T,P,CL area hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
BNM 3501	Radiopharmaceutical Chemistry	3	1	0	0	4	50	50	100
BNM 3502	Imaging Instruments in Nuclear Medicine	2	1	0	0	3	50	50	100
BNM 3503	Applications of computer in Nuclear Medicine	2	1	0	0	3	50	50	100
BNM 3504	Clinical Nuclear Medicine - I	3	1	0	0	4	50	50	100
BNM 3505	Practicum -V	0	1	4	0	3	50	50	100
BNM 3506	Clinical Practice - IV	0	1	0	6	3	50	50	100
Total		10	6	4	6	20	300	300	600

B.Sc. NMT SEMESTER VI

Course Code	Course Title	Credit Distribution (L,T,P,CL area hours/week)							
		Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	IAC	ESE	Total
BNM 3601	Tomography and Hybrid Imaging	3	1	0	0	4	50	50	100
BNM 3602	Introduction to AI and recent advances in nuclear medicine	3	1	0	0	4	50	50	100
BNM 3603	Clinical Nuclear Medicine - II	3	1	0	0	4	50	50	100
BNM 3604	Practicum - VI	0	2	4	0	4	50	50	100
BNM 3605	Clinical Practice - V	0	1	0	9	4	50	50	100
Total		9	6	4	9	20	250	250	500

B.Sc. NMT SEMESTER VII & VIII

SEMESTER VII				SEMESTER VIII			
Course	Duration	Credit	Contact Hours	Course	Duration	Credit	Contact Hours
Internship	6 months	20	900	Internship	6 months	20	900
Total	12 months (Clinical Learning = 48 hours / week)						

TOTAL DEGREE CREDIT DISTRIBUTION

Semester	Credit Distribution (L,T,P,CL area hours/week)					Contact Hours
	Lecture (L)	Tutorial (T)	Practical (P)	Clinical Learning (CL)	Credits	
Semester - I	14	4	4	0	20	330
Semester - II	10	5	6	6	20	405
Semester - III	10	5	6	6	20	405
Semester - IV	10	5	4	9	20	420
Semester - V	10	6	4	6	20	390
Semester - VI	9	6	4	9	20	420
Semester – VII Internship	0	0	0	48	20	900
Semester – VIII Internship	0	0	0	48	20	900
Total					160	4170

TOTAL MARKS DISTRIBUTION

Semester	Code	Subject	Credits	Marks		
				Internal	External	Total
1 st Semester	BNM-1101	Basics of Biochemistry and Cell Biology	4	50	50	100
	BNM-1102	Human Anatomy and Physiology for Nuclear Medicine	4	50	50	100
	BNM-1103	Solid state physics and Electronics in Nuclear Medicine	4	50	50	100
	BNM-1104	Fundamentals of Chemistry	3	50	50	100
	BNM-1105	Mathematics in Nuclear medicine	3	50	50	100
	BNM-1106 Practicum - I	Anatomy and Physiology Practicals	1	15	20	35
		Fundamentals of Chemistry Practicals	0.5	15	15	30
		Solid state physics and electronics and Radiation Physics Practicals	0.5	15	20	35
Total			20	-	-	600
2 nd Semester	BNM-1201	Introduction to Nuclear Medicine, Medical ethics and Patient care	3	50	50	100
	BNM-1202	Applied chemistry: Organic Chemistry & Inorganic chemistry for Nuclear Medicine	4	50	50	100
	BNM-1203	Radiation Physics	4	50	50	100
	BNM-1204	Fundamentals of Electromagnetism in Nuclear Medicine	3	50	50	100
	BNM-1205 Practicum - II	Cell and Molecular Biology Practical	1	10	15	25
		Biochemistry practical Practical	1	10	15	25
		Electricity and Magnetism Practical	1	10	15	25
		Applied chemistry Practical	1	10	15	25
	BNM-1206	Clinical Practice - I	2	50	50	100
	Total			20	-	-
3 rd	BNM-2301	Fundamentals of Immunology and Microbiology	3	50	50	100
	BNM-2302	Introduction to Radio pharmacy	4	50	50	100

Semester	BNM-2303	Nuclear Medicine Instrumentation Physics	4	50	50	100
	BNM-2304	Principles of wave and optical physics in biomedical imaging	3	50	50	100
	BNM-2305 Practicum - III	Radio pharmacy practical	1	20	20	40
		Nuclear Medicine Instrumentation practical	1	20	20	40
		Waves and Optics	1	10	10	20
	BNM-2306	Clinical Practice - II	3	50	50	100
Total			20	-	-	600
4th Semester	BNM-2401	Radiochemistry	4	50	50	100
	BNM-2402	Radiobiology	3	50	50	100
	BNM-2403	Biostatistics	3	50	50	100
	BNM-2404	Health Physics & Radiation Safety	4	50	50	100
	BNM-2405 Practicum - IV	Radiobiology Practical	1	15	15	30
		In vitro Nuclear Medicine techniques practical	0.5	10	10	20
		Health Physics and Radiation protection practical	1	15	15	30
		Nuclear medicine Physical Chemistry I practical	0.5	10	10	20
BNM-2406	Clinical Practice - III	3	50	50	100	
Total			20	-	-	600
5th Semester	BNM-3501	Radiopharmaceutical Chemistry	4	50	50	100
	BNM-3502	Imaging Instruments in Nuclear Medicine	3	50	50	100
	BNM-3503	Applications of computer in Nuclear Medicine	3	50	50	100
	BNM-3504	Clinical Nuclear Medicine - I	4	50	50	100
	BNM-3505 Practicum - V	Radiopharmaceuticals in Nuclear Medicine practical	1	15	20	35
		Clinical Nuclear Medicine - I	1	15	15	30
Therapeutic Nuclear Medicine		1	15	20	35	

	BNM-3506	Clinical Practice - IV	3	50	50	100
	Total		20	-	-	600
6th Semester	BNM-3601	Tomography and Hybrid Imaging	4	50	50	100
	BNM-3602	Introduction to AI and recent advances in nuclear medicine	4	50	50	100
	BNM-3603	Clinical Nuclear Medicine - II	4	50	50	100
	BNM-3604 Practicum - VI	Radiopharmacy Practices	1	10	15	25
		In-vitro Nuclear Medicine Practices	1	10	15	25
		Scintigraphy Practices	1	10	15	25
		Radiation Therapy Practices	1	10	15	25
	BNM-3605	Clinical Practice - V	4	50	50	100
Total		20	-	-	500	

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BNM1101 – BASICS OF BIOCHEMISTRY AND CELL BIOLOGY		
CONTENT	COMPETENCIES	NO. OF HOURS
Section A: Basic Biochemistry		
Unit 1: Enzymes		

CONTENT	COMPETENCIES	NO. OF HOURS
R N A synthesis & Processing	<ul style="list-style-type: none"> • List major types of RNA • Illustrate structure and function of RNA polymerase, its subunits and general transcription factors • Explain process of RNA synthesis and regulation • Explain RNA processing of ribosomal and transfer RNAs • Explain splicing and alternative splicing mechanisms • Explain RNA editing and degradation 	5
Translation	<ul style="list-style-type: none"> • Enlist components of translation • Explain structure of tRNA • amino acid activation, fidelity of aminoacyl tRNA synthetases • Explain the process of initiation of protein synthesis • Explain the process of elongation of peptide chain • Explain the process of termination of translation • Explain the role of stop codons 	5
M a i n References:	<ol style="list-style-type: none"> 1. Essentials of Biochemistry, U satyanarayana, U Chakrapani (2nd edition) 2. Handbook of Biochemistry for Allied & Nursing Students, Shivananda Nayak B (2nd edition) 3. Cell and Molecular Biology by de Robertis and de Robertis Llewellyn Pub 2001 4. Molecular Biology of the Cell by Alberts, Bray, Lewis, Raff, Roberts and Watson. Garland Science; 1997 	
Additional References:	<ol style="list-style-type: none"> 1. The Cell – A Molecular Approach by Geoffrey M. Cooper, ASM Press Washington, DC, Oxford University Press 2000. 2. Genes IX, Benjamin Lewin, Jones and Bartlett; 2008 3. Molecular Cell Biology by Darnell, Lodish, Baltimore, Scientific American Books 1990. 	

	<ul style="list-style-type: none"> • Define and classify “enzyme” • Explain “isoenzymes” with examples • Define the term “proenzyme or zymogen” with pepsinogen and trypsinogen as examples • Describe the utility of serum enzymes as diagnostic markers • Mention the diagnostic utility of following enzymes • CK • ALP • AST • ALT • LDH 	2
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Unit 2: Carbohydrates

	<ul style="list-style-type: none"> • Explain carbohydrates with examples for each class • Classify monosaccharides and mention the source and composition of following disaccharides • Lactose • Maltose • Classify polysaccharides based on composition with examples • Explain the structure of starch and glycogen with schematic representation • List the differences between starch and glycogen • Mention the occurrence and functions of heparin and chondroitin sulphate • Describe the complete digestion of dietary polysaccharides (starch and glycogen) • Describe the reactions catalyzed by the following brush border enzymes • Maltase • Sucrase-isomaltase • Lactase • Illustrate the mechanisms of absorption of monosaccharides in the small intestine • Explain the significance of including sodium chloride along with glucose in the oral rehydration solution • Define aerobic and anaerobic glycolysis • Mention the site and subcellular site of glycolysis • Describe the steps of glycolysis with all the enzymes and coenzymes at each step • Mention the regulatory enzymes and list the names of hormones that regulate it in the well-fed state and starvation • Calculate the energetics of aerobic and anaerobic glycolysis • Define gluconeogenesis 	11
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CONTENT	COMPETENCIES	NO. OF HOURS
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	<ul style="list-style-type: none"> • Mention the sites & subcellular sites of gluconeogenesis • List the precursors for gluconeogenesis • List the key enzymes of gluconeogenesis • Describe the synthesis of glucose from pyruvate and lactate • Mention the regulatory enzymes and list the names of hormones that regulate it in the well-fed state and starvation • Explain the significance of gluconeogenesis • Recall the reaction catalyzed by pyruvate dehydrogenase complex and mention its coenzymes • Mention the site and subcellular site of citric acid cycle • Describe the reactions of citric acid cycle with all enzymes and coenzymes • Mention the regulatory enzymes of citric acid cycle • Calculate the energetics of citric acid cycle • Mention the function of glycogen in liver and muscle • Define glycogenesis & glycogenolysis • Mention the site and subcellular site of glycogen metabolism • Mention the fate of end products of glycogenolysis in liver (role of glucose 6-phosphatase) and muscle • Mention the regulatory enzymes and the hormones involved in regulation in well-fed state and starvation • List the glycogen storage disorders mentioning their names, defects and tissues affected (Type I, V & VI) 	
Unit 3: Electron transport chain and oxidative phosphorylation		
	<ul style="list-style-type: none"> • Define the electron transport chain (ETC) • Name the subcellular site of ETC • Describe the complexes of ETC (with their components and order of arrangement) and mention the mobile electron carriers • Name the inhibitors for each of the complexes of ETC • Define oxidative phosphorylation 	3
Unit 4: Lipids		
	<ul style="list-style-type: none"> • Define lipids • Explain the functions of lipids in the body • Classify lipids with examples for all the subclasses. Classify fatty acids with examples-saturated, unsaturated (based on number of double bonds), essential fatty acids • Explain the process of emulsification of lipids • Describe the digestion of lipids in the stomach and intestine • Illustrate the process of absorption of lipids • Define steatorrhea and list its causes • Mention the site and subcellular site of de novo synthesis of fatty acids • List the sources of acetyl CoA for de novo synthesis of fatty acids • Explain the reaction catalyzed by acetyl CoA carboxylase 	7

CONTENT	COMPETENCIES	NO. OF HOURS
Section B: Cell Biology		
Plasma Membrane, Nucleus and Mitochondria	<ul style="list-style-type: none"> • List theories of origin of life • Explain theories on molecular architecture of plasma membrane. Explain structure of plasma membrane and outline chemical composition of plasma membrane • Explain transport of molecules-active and passive • Explain role of ion channels in cellular transport • Illustrate cell-cell interaction • Demonstrate organization of Nucleus and chromosomes • Illustrate structure and function of nuclear Envelope and nuclear pore complex • Explain selective transport of proteins across nuclear pore (Import) • Explain selective transport of proteins across nuclear pore (Export) • Explain Internal organization of nucleus, chromosomes and chromatin structure • Explain structure and function of nucleolus • List functions of peroxisomes • Demonstrate peroxisomal assembly and biochemical characterization • Explain glyoxylate cycle • Explain Photorespiration 	5
Protein sorting and transport	<ul style="list-style-type: none"> • Define endoplasmic reticulum, golgi apparatus and lysosomes • Explain general organization of endoplasmic reticulum and targeting of proteins to endoplasmic reticulum • Explain Insertion of proteins into endoplasmic reticulum membrane • Explain Quality control in Endoplasmic reticulum • List functions of smooth endoplasmic reticulum • Explain role of Smooth endoplasmic reticulum in lipid synthesis • Demonstrate organization of Golgi apparatus • Explain protein sorting and export from Golgi apparatus . Explain lysosome formation 	5
Cell signaling	<ul style="list-style-type: none"> • List modes of cell-cell signaling • Explain G Protein-coupled receptor, receptor Protein Tyrosine kinases and cytokine receptors organization • Enlist intracellular signal transduction pathways, Explain cAMP pathway, cyclic GMP, Phospholipids, Ca²⁺ PI-3Kinase/Akt, mTOR and MAP kinase pathways 	5
DNA structure and DNA replication	<ul style="list-style-type: none"> • Enlist different types of DNA (A, B and Z DNA) • Understand DNA helix structures and function of Restriction endonucleases • Explain function of DNA ligases, topoisomerases and gyrase • Explain supercoiling of DNA • Explain semiconservative and semi-discontinuous nature of DNA synthesis • Explain structure, components and function of DNA polymerase • Explain process of DNA synthesis 	5

BNM1102 – HUMAN ANATOMY AND PHYSIOLOGY IN NUCLEAR MEDICINE

CONTENT	COMPETENCIES	NO. OF HOURS
SECTION A: HUMAN ANATOMY IN NUCLEAR MEDICINE		
Unit 1: General Anatomy, Locomotion and Support		
	<ul style="list-style-type: none"> • Define the Anatomical position and Anatomical terms • Explain the epithelium - types and functions • Explain the connective tissue–fibers and cells • Cartilage – types, examples and histology Bone – classification, examples and histology. Parts of long bone, names of all bones, vertebral column and intervertebral disc. Fontanel’s of fetal skull • Joints – classification of joints with examples, typical synovial joint (in detail) • Muscular system – classification of muscular tissue and histology Important muscles of the body- Sternocleidomastoid, Trapezius, Muscles of tongue, Deltoid, Biceps brachii, Intercostal muscles, Thoracic diaphragm, Rectus abdominis, External oblique, Internal oblique, Transversus abdominis, Pelvic diaphragm, Gluteus maximus, Gluteus medius, Gluteus Minimus, Quadriceps femoris, Soleus 	4
Unit 2: Respiratory system		
	<ul style="list-style-type: none"> • List the parts of respiratory tract, nose, nasal cavity, paranasal air sinuses, larynx, trachea, lungs, pleura • Explain the trachea: Extent, Structure and nerve supply • Explain the diaphragm - attachments, nerve supply and actions • Explain the thoracic cage: thoracic wall, intercostal spaces and their contents • Explain the Lungs- gross anatomy, roots of the lungs, surface marking of pleura and lungs • Explain the pleura- parts, pleural cavity, pleural recesses, pulmonary ligament 	4
Unit 3: Cardiovascular system		

	<ul style="list-style-type: none"> • Explain the heart - position, external features, right atrium internal features • Explain the right ventricle internal features, Blood supply to the heart • Explain the left atrium and left ventricle, nerve supply of heart • Explain the pericardium - Parts, blood supply, nerve supply and function • Explain the mediastinum - boundaries and contents • List and explain the arteries - Arch of aorta and descending thoracic aorta (extent course and branches) • Histology of heart 	4
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Unit 4: Digestive system

	<ul style="list-style-type: none"> • List the parts of digestive system • Explain the tongue–gross anatomy, blood supply and nerve supply • Explain the salivary glands- Names and location 	5
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	<ul style="list-style-type: none"> • Explain the esophagus - extent, parts, constrictions, blood supply, nerve supply and lymphatic drainage • Explain the stomach- position, relations, blood supply, nerve supply and lymphatic drainage • Explain the duodenum- parts, important relations, blood supply and nerve supply • Explain the pancreas–position, parts, important relations, blood supply and nerve supply • Explain the small intestine–parts- duodenum, jejunum and ileum- blood supply and nerve supply • Explain the large intestine–parts, position of each of the parts, extent, blood supply and nerve supply • List the differences between jejunum and ileum • List the differences between small intestine and large intestine • Explain the rectum and anal canal-position, blood supply, nerve supply and lymphatic drainage • Explain the liver- position, anatomical and physiological lobes, surfaces, relations, porta hepatis, blood supply and nerve supply • Explain the extrahepatic biliary apparatus–gall bladder and bile duct 	
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Unit 5: Renal system

	<ul style="list-style-type: none"> • List the parts of urinary system • Explain the kidneys: position, external features, capsules, relations, macroscopic structure, blood supply and nerve supply • Explain the ureter- length, constrictions and blood supply • Explain the urinary bladder- position, external features, blood supply and nerve supply • Explain the urethra- female urethra, male urethra- parts 	2
Unit 6: Reproductive System		
Male reproductive system	<ul style="list-style-type: none"> • List the parts of male reproductive system • List the spermatic cord- constituents and coverings • Explain the testes- position, coverings, gross structure, blood supply, nerve supply and lymphatic drainage • Explain the vas deferens- commencement, course and termination • Explain the prostate–position, external features, lobes and structure • Explain the seminal vesicles and ejaculatory ducts 	2
Female reproductive system	<ul style="list-style-type: none"> • Name the parts of female reproductive system • Explain the uterus-position, parts, external features, relations, blood supply and lymphatic drainage • Explain the uterine tube- parts, blood supply and nerve supply • Explain the ovary – position and structure 	2

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 7: Endocrine Gland and Special Senses		
Endocrine Glands	<ul style="list-style-type: none"> • Name the endocrine glands • Explain the pituitary gland (Hypophysis cerebri)- position, parts, blood supply • Explain the suprarenal glands- position, relations, parts, blood supply and lymphatic drainage • Explain the thyroid gland- position, parts, blood supply and lymphatic drainage • Name the parathyroid glands-their position and blood supply • Recall the gross anatomy of the eye • Recall the gross anatomy of external, middle and internal ear • Recall the skin and its features 	2
Unit 8: Central Nervous system		

	<ul style="list-style-type: none"> • List the features and explain the spinal cord- position, external features, internal structure, brief note on important ascending and descending tracts • Name the parts of brain • Explain the cerebellum- functional lobes of the cerebellum and its functions • Explain the midbrain- external features and internal structure–in brief • Explain the cranial nerves • Explain the cerebral hemispheres–lobes, important sulci and functional areas • Explain the corpus callosum and internal capsule • Explain the diencephalon- Thalamus and hypothalamus position and functions • Explain the basal nuclei: Corpus striatum–parts and functions • Explain the blood supply to the central nervous system • Explain the ventricles • Define the CSF production and circulation 	6
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CONTEN T	COMPETENCIES	NO. OF HOURS
SECTION B: HUMAN PHYSIOLOGY FOR NUCLEAR MEDICINE		
Unit 1: Basic concepts and General physiology		

<p>Blood</p>	<ul style="list-style-type: none"> • Describe the Composition and functions of blood • Name the different types of plasma proteins and list their functions • Mention the morphology and functions of red blood cells • Mention the normal count of RBC and its variations • Describe the sites, stages and factors influencing erythropoiesis • Mention the normal value of hemoglobin concentration and its variations • Mention the functions of hemoglobin • Define anemia and describe the morphological classification of anemia • Classify White Blood Cells (WBC) • List the functions of WBCs • Mention the normal count of various types of WBCs • State Landsteiner’s law • Describe the ABO and Rh systems of blood grouping • Explain the importance of blood grouping • Mention the hazards of blood transfusion • Explain the cause and clinical features of hemolytic disease of the newborn (erythroblastosis fetalis) • List the functions of lymph 	
<p>Unit 2: Cardiovascular System</p>		
	<ul style="list-style-type: none"> • Organization of cardiovascular system, greater and lesser circulation • Physiological anatomy of the heart, nerve supply, Junctional tissues of heart (pacemaker) • Cardiac cycle: Mechanical events, Heart sounds, causes, characteristics and significance • Normal ECG, clinical significance of ECG, Heart rate – Physiological variations • Cardiac output: Definitions, normal values, physiological variations • Arterial blood pressure: Definitions, normal values, physiological variations, factors maintaining blood pressure. 	
<p>Unit 3: Respiratory System</p>		
	<ul style="list-style-type: none"> • Respiratory and non-respiratory function of respiratory system • Physiological anatomy of respiratory system • Functions of respiratory tract, Respiratory membrane, Respiratory muscles, Surfactant: functions, respiratory distress syndrome • Definitions of terms used in respiratory physiology: Eupnea, Hyperpnoea, Tachypnea, Apnea, Dyspnea • Mechanics of breathing – intrapulmonary and Intrapleural pressure changes during a respiratory cycle • Spirometry – Lung volumes and capacities. Vital capacity • Define pulmonary and alveolar ventilation and mention the normal values • Define anatomical dead space 	

CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • Mention the normal value of anatomical dead space • Oxygen transport: Role of hemoglobin, factors affecting, oxygen carrying capacity. Carbon dioxide transport: forms, chloride shift (Hamburgers phenomenon) • Partial pressure of gases, Calculation of partial pressure of gasses in mixture. Arterial and venous blood gas concentrations and contents • Hypoxia: Types and effects Cyanosis, Asphyxia, Periodic Breathing, Acclimatization 	
Unit 4: Renal System		
	<ul style="list-style-type: none"> • Functions of kidneys. Nephrons – Juxta glomerular apparatus – functions, Steps in Urine formation – Ultrafiltration, Tubular Reabsorption, Tubular Secretion, GFR • Definition, normal values, factors affecting GFR, measurement of GFR, Renal threshold for glucose, tubular load for glucose • Role of aldosterone and ADH in urine formation, Micturition, Innervation of bladder • What is Diuresis • Mention Renal functions tests – Based on analysis of urine and analysis of blood, Skin: Functions of skin Sweat glands 	
Unit 5: Digestive System		
	<ul style="list-style-type: none"> • Introduction and structure of digestive tract • Describe the composition and function of alimentary canal, Saliva • Describe the composition and function of Stomach • Describe the composition and function of Pancreas • Describe the composition and function of Liver • Describe the composition and function of Gall bladder • Describe the composition and function of Succus entericus • Describe the composition and function of large intestine, Movements of small intestines • Describe Deglutition 	
Unit 6: Endocrine System		

<ul style="list-style-type: none"> • Define and mention the functions of Major endocrine glands and their Hormone • Define Anterior pituitary: hormones and mention their functions, disorders like Gigantism, acromegaly, dwarfism • Define and mention Posterior pituitary: Hormones – diabetes insipidus • Define and mention Thyroid: Hormones, normal values, functions, role of TSH • What is simple goitre, myxoedema, cretinism, Grave’s disease? • Define and mention Adrenal cortex: hormones, functions of cortisol and aldosterone. • Explain briefly Addison’s disease, Cushing’s syndrome • Define and mention Adrenal medulla: actions of adrenaline and noradrenaline • Define and mention Endocrine pancreas: Insulin & glucagon, functions, Regulation of blood glucose level, diabetes mellitus • Define and mention Parathyroid: Functions of PTH 	
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CONTENT	COMPETENCIES	NO. OF HOURS
Unit 7: Nervous System		
	<ul style="list-style-type: none"> • What are Classification Organization of spinal cord • Mention the functions of Dorsal column and Spinothalamic tract • What are the functions of Corticospinal tract • What is Reflex Action • Definition, reflex arc • Mention the functions of Cerebellum, Basal ganglia, Thalamus, Hypothalamus, Cerebral cortex: Lobes & functions. • EEG – Definition and uses • What is Autonomic nervous system: Organization & functions • What is Cerebrospinal fluid: Composition and function 	
Unit 8: Special Senses		
	<ul style="list-style-type: none"> • Vision: Physiological anatomy of eye ball, rods & cones, Refractive errors: Myopia, hypermetropia, presbyopia & astigmatism • Audition: Functions of outer, middle & inner ear, cochlea, Deafness – types • Taste: Taste buds, primary taste sensation, Smell: Receptors, modalities of smell 	
Unit 9: Reproductive System		
	<ul style="list-style-type: none"> • Male reproductive system: functions of testes, puberty, spermatogenesis functions of testosterone, semen • Female reproductive system: Ovarian hormones functions – Menstrual cycle • Hormonal basis of changes in menstrual cycle • Enumerate the functions of placenta • Describe milk ejection reflex • Mention various contraceptive methods in males • Mention various contraceptive methods in females • Explain the mechanism of action of various contraceptive methods 	
Unit 10: Lymphatic system		

	<ul style="list-style-type: none"> • Explain the role of Lymphoid Tissue in Immune Surveillance • Describe the function of the secondary lymphoid organs (Spleen, MALT) as filters and sites of immune cell interaction • Detail the process of immune cell circulation and activation within the lymphatic network • Briefly explain the metabolic role of lacteals in fat absorption (chyle) • Explain the role of the Lymph Node as the Primary Filter • Describe the microanatomy of a lymph node (cortex, medulla, sinuses) and how it facilitates fluid filtration • Explain the physiological basis of lymph node enlargement (Lymphadenopathy) in response to infection or malignancy • Detail the entry and filtering of pathogens, cancer cells, and cellular debris • Explain the role of Lymphatic Physiology in Nuclear Medicine Imaging • Describe the physiological principle behind Lymphoscintigraphy: using lymphatic transport to guide radiotracer uptake and flow 	
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CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • Explain how the lymphatic drainage pathway is mapped to perform Sentinel Lymph Node (SLN) localization for cancer staging • Relate lymphatic failure to the clinical condition of Lymphedema 	
M a i n Reference:	<ol style="list-style-type: none"> 1. Human Anatomy by Dr. B. D. Chaurasia (Vol 1,2,3,4) 2. Grays’ Anatomy International edition 42e 3. Basics of Medical Physiology,4th edition, D.Venkatesh, H.H.Sudhakar 4. Guyton and Hall Textbook of Medical Physiology 5. Ross and Wilson Applied Anatomy and applied physiology 	

Additional References	1. Chaurasia's handbook of human anatomy 2. Netter's Atlas	
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BNM1103 – SOLID STATE PHYSICS AND ELECTRONICS IN NUCLEAR MEDICINE

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Solid State Physics in Nuclear Medicine		

Crystal structure	<ul style="list-style-type: none"> • Classify solids into crystalline and amorphous, and explain isotropy vs. anisotropy • Define lattice points, unit cells, and crystal systems; describe lattice parameters • Identify and describe Bravais lattices in 2D and 3D and types of cubic lattices (simple, BCC, FCC) • Describe types of crystal bonding: ionic, covalent, metallic, and molecular (van der Waals) • Identify crystal defects: point defects (vacancy, interstitial, substitutional), dislocations, and surface defects • Analyze effects of defects on electrical and optical (scintillation, etc.) properties of materials • Explain the properties and applications of scintillator crystals (NaI (Tl), BGO, LSO, etc.) in Nuclear Medicine • Describe structural features, role of activators, and their influence on energy resolution in scintillator crystals 	8
Electronic Properties of Solids	<ul style="list-style-type: none"> • Describe the free electron model and discuss its limitations • Explain the formation of energy bands in solids and the band theory of solids • Classify materials based on band structure: conductors, semiconductors, and insulators • Describe intrinsic semiconductors, carrier generation, energy gap, and conductivity • Explain extrinsic semiconductors, including n-type and p-type doping, donor and acceptor levels • Define Fermi energy and the Fermi-Dirac distribution; explain temperature dependence • Explain carrier mobility, diffusion, drift current, and recombination processes • Describe the p-n junction diode structure and operation • Explain the Hall effect, derive the Hall coefficient, and discuss applications • Discuss applications of semiconductors in Nuclear Medicine: CZT and Si photodiodes in radiation detection, semiconductor-based gamma cameras 	15
Magnetic and Dielectric Properties of Materials	<ul style="list-style-type: none"> • Define origin of magnetic moment and Bohr magneton (C1) • Explain the concept of magnetic moment and its quantum origin (C2) • Classify magnetic materials: diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferrimagnetic (C2) • Describe magnetization curves including hysteresis loop, coercivity, retentivity, and magnetic energy loss (C2) • Analyze the features of magnetization curves related to magnetic properties • Explain magnetic susceptibility and permeability and their temperature dependence according to Curie and Curie-Weiss laws • Describe polarization mechanisms in dielectric materials: electronic, ionic, dipolar, and space charge polarization 	8
CONTENT	COMPETENCIES	NO. OF HOURS

	<ul style="list-style-type: none"> • Explain dielectric constant and loss, dielectric strength, energy storage, and breakdown phenomena • Discuss frequency dependence of dielectric properties and dielectric hysteresis • Apply knowledge of magnetic properties of materials in shielding used in PET/MR • Apply knowledge electrical properties of materials to design a dielectric for high-voltage isolation • Analyze the role of magnetic and dielectric materials in these applications 	
Unit 2: Devices and Electronics		
Components of electrical circuits used in Nuclear Medicine devices	<ul style="list-style-type: none"> • Define resistors, capacitors, inductors, and transformers, and explain their basic properties and circuit behavior • State and apply Ohm's Law for current, voltage, and resistance relationships in circuits • Explain Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL) and apply them in circuit analysis • Describe the variation of resistivity with temperature • Interpret and analyze the I-V characteristics of diodes • Describe Zener diode functions and applications • Explain the behavior and characteristics of Bipolar Junction Transistors (BJT) in Common Base (CB), Common Emitter (CE), and Common Collector (CC) modes 	8
Amplifiers, Rectifiers and Power Supplies	<ul style="list-style-type: none"> • Describe types of amplifiers, gain concept, and applications • Explain the common emitter amplifier • Explain single-stage and two-stage coupled amplifiers and their operation • Describe operational amplifier characteristics and configurations: inverting, non-inverting, and comparator • Explain rectifiers: half-wave, full-wave, bridge rectifiers; define ripple factor and filters used for smoothing • Classify transducers types and explain their use in Nuclear Medicine (e.g., dose monitors, pressure sensors) • Describe LEDs and CRTs as display components and indication systems • Classify power supplies: linear, switching types; explain voltage stabilizers, regulators, SMPS, and inverters • Describe pulse shaping methods including Gaussian shaping and CR-RC networks and their role in resolution enhancement • Apply knowledge of voltage regulation and signal processing in Nuclear Medicine imaging systems 	8
Electronic filters and circuits in Nuclear Medicine devices	<ul style="list-style-type: none"> • Define low-pass, high-pass, and band-pass filters and explain their applications in signal conditioning • Explain timing discriminators and gating circuits and their functions in signal processing • Apply event selection and noise reduction techniques in Nuclear Medicine instrumentation 	6

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 3: Boolean Algebra		
Binary system and Truth tables	<ul style="list-style-type: none"> • Define the binary number system and explain its base-2 structure • Convert numbers from one number system to another, including binary to decimal and vice versa • Perform binary addition and subtraction operations • Define logic gates: AND, OR, NOT, NAND, NOR, XOR • Construct truth tables for individual logic gates • Combine multiple logic gates to create logical circuits • Apply De Morgan's theorem to simplify logical expressions and circuits • Explain the working of ADCs and DACs in signal conversion for digital instrumentation • List applications of digital circuits and signal processing in Nuclear Medicine 	7
Main Reference:	<ul style="list-style-type: none"> • Solid State Physics Charles Kittel, "Introduction to Solid State Physics" Wiley India UG/PG, reser • Devices & Electronics Streetman & Banerjee, "Solid State Electronic Devices" • Devices (Fundamentals) Nair & Somanathan, "Solid State Devices" Applied Electronics R.S. Sedha, "A Textbook of Applied 	
Additional References	<ul style="list-style-type: none"> • Solid State Physics S.L. Kakani & C. Hemrajani, "Solid State Physics" Sultan Chand & Sons 	

BNM1104 – FUNDAMENTALS OF CHEMISTRY		
CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Introduction to Chemistry and Atomic Theory		
	<ul style="list-style-type: none"> • Define fundamental terms like atom, molecule, element, compound, and the laws of chemical combination • Explain the concepts of mole, molar mass, and percentage composition • Solve problems to calculate empirical and molecular formulae and stoichiometry • Write electronic configurations for various elements and ions using the Aufbau principle, Pauli exclusion principle, and Hund's rule 	8
Unit 2: Chemical kinetics and thermodynamics		
	<ul style="list-style-type: none"> • Explain the basic laws of thermodynamics, reaction rates, and equilibrium concepts • Describe the physical properties of matter, including surface tension, viscosity, and vapor pressure 	5
Unit 3: Periodic table and periodicity		
	<ul style="list-style-type: none"> • Describe the periodic classification of elements • Compare and contrast periodic trends such as atomic and ionic radii, ionization enthalpy, electron affinity, and electronegativity • Explain how effective nuclear charge influences these periodic trends 	8
Unit 4: Chemical bonding, hybridization & molecular orbital theory		
	<ul style="list-style-type: none"> • Explain the basic principles of chemical bonding, including Valence Bond Theory and the types of bonds (ionic, covalent) • Draw Lewis structures for simple molecules • Determine the molecular geometry of compounds using VSEPR theory and hybridization concepts • State the laws of chemical combination (conservation of mass, definite and multiple proportions) 	10
Unit 5: Basic chemical laws and introduction to organic chemistry		
	<ul style="list-style-type: none"> • Explain fundamental concepts of organic chemistry, including electronic effects (resonance, inductive, hyper conjugation) and steric effects • Use electronic and steric effects to explain the acid/base properties of organic compounds • Describe the principles of optical isomerism and stereocenters • Predict the conformations of acyclic and cyclic systems, such as substituted ethane's and cyclohexenes 	11

Main Reference:	<ol style="list-style-type: none"> 1. Lee, J.D. Concise Inorganic Chemistry ELBS, 1991. 2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970 3. Atkins, P.W. & Paula, J. Physical Chemistry, 10th Ed., Oxford University Press, 2014. 4. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962. 5. Rodger, G.E. Inorganic and Solid State Chemistry, Cengage Learning India Edition, 2002 6. Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley. 7. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India, 2006. 8. Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010. 9. Graham Solomon, T.W., Fryhle, C.B. & Snyder, S.A. Organic Chemistry, John Wiley & Sons (2014). 10. McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013. 11. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1998) 12. Eliel, E.L. Stereochemistry of Carbon Compounds, Tata McGraw Hill education, 2000. 13. Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S 	
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BNM1105 – MATHEMATICS IN NUCLEAR MEDICINE

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Basic mathematical concepts		
Vector analysis	<ul style="list-style-type: none"> • Recall the definitions of vector addition, dot product, cross product, gradient, divergence, and curl • Describe the geometric and physical meaning of curl and divergence • Solve problems involving derivatives and integrals of vector functions • Distinguish between conservative and non conservative vector fields 	3

Matrices	<ul style="list-style-type: none"> • List the rules for matrix addition, subtraction, scalar multiplication, and matrix multiplication • Explain how matrix multiplication can represent data organization • Perform operations on matrices and apply them to image or data matrices • Examine the structure and transformation of a matrix representing image data • State the definitions of eigenvalues and eigenvectors • Describe the significance of eigenvalues and eigenvectors in linear systems • Compute eigenvalues and eigenvectors for given matrices • Compare eigenvalues of different matrices and analyze their implications • State the properties and definitions of matrices and determinants • Summarize the geometric meaning of determinants • Solve for determinants and use matrices to solve linear systems • Break down the concepts of invertibility and rank of matrices • Recall the forms and properties of complex numbers • Explain the effect of complex multiplication on rotation and scaling • Solve equations and perform arithmetic operations with complex numbers • Compare polar and rectangular representations 	6
Trigonometry & Functions and Application in Nuclear Medicine	<ul style="list-style-type: none"> • Define trigonometry, angles, allied angles, and inverse functions • Explain the foundational concepts of trigonometry and angle types • Apply trigonometric identities and functions to solve problems • Analyze how allied angles and inverse functions modify solutions • Apply the use of trigonometry and its functions to real-world or mathematical problems • Analyze problem statements to select appropriate trigonometric approaches • Recall principles of graphical representation in nuclear medicine • Describe common types of medical and nuclear imaging graphs • Use graphical data to extract or demonstrate clinical information • Analyze features of nuclear medicine graphs for diagnostic interpretation • Define polynomial functions and identify basic properties • Describe characteristics of exponential functions • Apply polynomial and exponential models to physical or data-based scenarios • Analyze graphs and behavior of polynomial vs. exponential functions • Explain the growth and decay models using exponential and logarithmic functions • Apply exponential and logarithmic equations to solve real-world problems 	8

CONTENT	COMPETENCIES	NO. OF HOURS
Limits & Derivatives	<ul style="list-style-type: none"> • Define limit and state its relevance in calculus • Explain derivative • Apply differentiation to standard functions • Analyze the use of derivatives to find rate of change in standard functions • State the fundamental rules of differentiation • Explain how rules of differentiation are used • Apply differentiation rules to composite functions • Analyze the structure of composite functions and their derivatives • Apply differentiation techniques to implicit functions • Analyze how to extract dy/dx from implicit relationships between variables • Apply differentiation techniques to logarithmic functions • Analyze the results of differentiating logarithmic functions • Explain successive differentiation • Apply successive differentiation to various functions • Analyze patterns and results in higher derivatives 	8
Unit 2: Advanced mathematical concepts		
Integration	<ul style="list-style-type: none"> • Define integration and explain an indefinite integral • Describe the concept and purpose of the indefinite integral • Explain the method of integration by substitution • Apply integration by substitution to solve integrals • Analyze when and how substitution simplifies integration problems • Explain the method of integration by partial fractions • Apply partial fraction decomposition to integrate rational functions • Analyze the structure of rational functions to perform partial fraction integration • Describe the integration by parts method • Apply integration by parts to solve integrals • Analyze the parts of an integral to decide suitable functions for integration by parts • State and explain properties of definite integrals 	8

Differential Equations and its application in Nuclear Medicine	<ul style="list-style-type: none"> • Define differential equations and their significance • Explain the basic concepts behind differential equations • Solve given ordinary differential equations • Analyze solution methods for differential equations • Construct differential equations from physical or mathematical problems • Analyze and solve constructed differential equations in context • Derive the attenuation coefficient equation for materials • Analyze the physical meaning and implications of the attenuation coefficient • Derive the exponential decay equation for radioactive activity • Justify the exponential decay model for activity decaying processes 	8
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CONTENT	COMPETENCIES	NO. OF HOURS
Application of mathematics in radiopharmacy and health physics	<ul style="list-style-type: none"> • Derive the Bateman equation and analyze its application in radioactivity calculations • Define unit conversion and explain specific concentration of activity • Solve problems related to radiation exposure rate • Analyze radiation exposure in different scenarios 	6
Main Reference:	<ol style="list-style-type: none"> 1. Mathematical Methods in the Physical Sciences – Mary L. Boas 2. Physics in Nuclear Medicine – Simon Cherry, James Sorenson, Michael Phelps 3. Basic Physics in Nuclear Medicine – Gopal B. Saha 4. Additional References: 5. Introduction to Mathematical Physics – Charlie Harper 6. Introduction to Probability and Statistics – Mendenhall & Beaver 7. Practical Statistics for Medical Research – Douglas G. Altman 8. Physics in Nuclear Medicine- Sorenson 9. Quality control of Nuclear Medicine instruments Tecdoc-602 10. Radiation Detection and Measurement- Knoll G.F 	
Additional References	<ol style="list-style-type: none"> 1. Mosby’s Manual of Nuclear Medicine Procedures D.Brucee Sodes, Paul J Early 2. Nuclear Medicine-Robert E. Henkin, Mark A. Boles 3. Computers in Nuclear Medicine-Lee Kai Hi 	

BNM1106 – PRACTICUM - I

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Solid state physics and electronics		
Fundamentals of Solid-state physics and Electronics	<ul style="list-style-type: none"> • To demonstrate the working of a digital multimeter and measure resistances of given resistors and compare with color coding values • To measure capacitance of given set of capacitors using digital multimeter and compare with calibrated values • To test diodes using digital multimeter • To measure voltage output from a given source using digital multimeter and find error in the measured values • To measure voltage and frequency of a given signal using digital oscilloscope • To demonstrate the operation of low pass and high pass filter using oscilloscope • Determination of reverse saturation current and material constant of PN junction also determine energy band gap • Determine the energy gap of a semiconductor using experimental measurements and analyze its significance 	20
Unit 2: Radiation Physics		
Radiation physics Practical	<ul style="list-style-type: none"> • To demonstrate functioning of various parts of a gamma ray spectrometer • To observe the gamma ray energy spectrum of Cs137, Ba-133, Co-57, Co-60, etc, radioisotopes and identify various types of processes • To demonstrate working of a NaI (Tl) detector and observe its output on an oscilloscope • To determine the half value layer of lead, copper, aluminum etc. for Ba- 133 • To determine the half value layer of lead, copper, aluminum etc. for Cs- 137 • To determine the half value layer of lead, copper, aluminum etc. for Tc- 99m 	10
Unit 3: Fundamentals of chemistry		
Unit 3: Fundamentals of chemistry	<ul style="list-style-type: none"> • To demonstrate the use of apparatus (weighing balance, pipettes, pH meter etc.) • To estimate the amount of carbonate and hydroxide/bicarbonate present together in mixture • To conduct the pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base (iii) weak acid-weak base (iv) Strong acid-weak base • Determination of dissociation constant of a weak acid • Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture • Estimation of water of crystallization in Mohr's salt by titrating with KMnO₄ • Identification of Cations and anions by qualitative analysis (chemical confirmatory tests) 	10
Unit 4: Anatomy and Physiology		

Unit 4: Anatomy and Physiology	<ul style="list-style-type: none"> • To identify and demonstrate the anatomy and physiology of major organs and systems including skeletal, cardiovascular, respiratory, gastrointestinal, urinary, endocrine, and nervous systems using models, charts, and imaging correlations • To identify surface anatomy and anatomical landmarks important for patient positioning and radiopharmaceutical imaging procedures. • To measure and record vital physiological parameters including pulse rate, respiratory rate, blood pressure, temperature, and oxygen saturation relevant to patient preparation and monitoring 	20
Main Reference	<ol style="list-style-type: none"> 1. Practical electronics handbook by Ian Sinclari 2. Practical Physics vol-3 by Dr Vinod Goel 3. Solid State Physics by Kakani SL and Hemarajini 4. Principle Medical Electronics and Biomedical Instrumentation by R.C Rajan, Guha S K 5. Physics in Nuclear Medicine by Sorenson 6. Quality control of Nuclear Medicine instruments by Tecdoc 602 7. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009. 8. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011). 9. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003). 10. Ogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Text book of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996. 11. Human Anatomy by Dr. B. D. Chaurasia (Vol 1,2,3,4) 12. Grays' Anatomy International edition 42e 13. Basics of Medical Physiology, 4th edition, D.Venkatesh, H.H.Sudhakar 14. Guyton and Hall Textbook of Medical Physiology 15. Ross and Wilson Applied Anatomy and applied physiology 	
Additional references	<ol style="list-style-type: none"> 1. Radiation Detection and Measurement- Knoll G. F. 2. Introductory Nuclear Physics- Krane K. S. 3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960. 4. Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003). 5. Chaurasia's handbook of human anatomy 6. Netter's Atlas 	

**BNM1201 – INTRODUCTION TO NUCLEAR MEDICINE, MEDICAL ETHICS
AND PATIENT CARE**

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Fundamentals of Nuclear Medicine and Imaging	<ul style="list-style-type: none"> • Define and understand diagnostic and therapeutic roles and application of nuclear medicine in disease detection • Define the basic terminologies of radiopharmacy (e.g. tracer uptake, dose etc.) • Explain the administration routes of dosing in nuclear medicine • Explain the properties of common agents used in nuclear medicine like Tc-99m, I-131, F-18 FDG and its applications in clinical protocols • Explain the working of diagnostic nuclear medicine facility • Explain the working of therapeutic nuclear medicine facility 	4
Unit 2		
Medical Terminology basics	<ul style="list-style-type: none"> • List the basic medical terminology, abbreviation and symbols and their application in documentation • List the basic anatomical terminology, abbreviation and symbols and their application in documentation • List the basic pathological and diagnostic terminology, abbreviation and symbols and their application in documentation • List the basic pharmacological terminology, abbreviation and symbols and their application in documentation • List the basic clinical procedure terminology, abbreviation and symbols and their application in documentation 	4
Unit 3		
Medical ethics	<ul style="list-style-type: none"> • Outline historical overview of bioethics • Define goal, scope, prayer, oath, covenants, declarations • Explain guidelines and basic principles of medical ethics 	3
Organizational Ethics	<ul style="list-style-type: none"> • Explain Malpractice and negligence - Rational and irrational drug therapy • Explain the risk benefit analysis, compensation, care of terminally ill patient and euthanasia • What is an informed consent? • Explain autonomy and informed consent - Right of patients • Explain Professional Indemnity insurance policy and development of standardized protocol to avoid near miss or sentinel events 	6

Hospital organization and procedure	<ul style="list-style-type: none"> • Explain the hospital organization • Explain organization and functioning of nuclear medicine unit/department • Explain maintenance of hospital records and stocks • Explain importance of professional attitude towards patients and other members of the staff • List do's and don'ts for patient safety during various clinical/diagnostic procedures 	8
Care of the patient	<ul style="list-style-type: none"> • Demonstrate patient care in Diagnostic Nuclear Medicine • Demonstrate patient care in Therapeutic Nuclear Medicine • Explain patient care and safety at both organization and department level 	6

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 4		
Medico legal aspects of medical records	<ul style="list-style-type: none"> • What are patient rights and privacy laws • What is Medico legal case and type- Records and document related to MLC - ownership of medical records? • Explain the confidentiality privilege communication • Explain release of medical information - Unauthorized disclosure and retention of medical records - other various aspects • Understand healthcare facility regulations • Understand Radiation safety regulations and its applications in nuclear medicine • Understand professional standards and conduct 	4
Unit 5		
Drugs in the department	<ul style="list-style-type: none"> • Understand the application of different drugs in nuclear medicine • List the emergency drugs in nuclear medicine 	3
Acquaintance of equipment	<ul style="list-style-type: none"> • Define and explain the principles of the various radiation/non-radiation equipment/devices available in Nuclear Medicine department • Explain the setting of trays, trolleys and emergency instruments in the Nuclear Medicine patient handling area • Explain the methods of sterilization and use of CSSD 	7

Main Reference:	<ol style="list-style-type: none"> 1. Hazel Biggs-Healthcare Research Ethics and Law. Regulation, Review & Responsibility. (2010). Cavendish Biomedical Law & Ethics Library 2. Care of patient in diagnostic Radiography By: Chesney & Chesney. 3. Chesney's Care of the patient in Diagnostic Radiography By: Pauline J Culmer. 4. Aid to Tray and Trolley Setting By: Marjorie Houghton 5. Medical Terminology for Health Professions – Ann Ehrlich, Carol L. Schroeder, Cengage Learning; detailed guide to medical language and communication. 	
Additional References	Bonnie F. Fremgen – Medical Law and Ethics, Pearson Education	

**BNM1202 – APPLIED CHEMISTRY: ORGANIC CHEMISTRY & INORGANIC CHEMISTRY
FOR NUCLEAR MEDICINE**

CONTENT	COMPETENCIES	NO. OF HOURS
Section A: Organic Chemistry for Nuclear Medicine		
Unit 1:		
Organic reaction mechanism and synthetic applications	<ul style="list-style-type: none"> • Compare and contrast the mechanisms of different rearrangement reactions (e.g., Pinacol pinacolone vs. Favorskii) • Use organometallic reagents (e.g., Grignard, organolithium) to perform specific transformations in organic synthesis • Solve structural problems by using a series of chemical reactions to identify an unknown compound 	5
Unit 2:		
Qualitative organic analysis	<ul style="list-style-type: none"> • Explain chemical tests to identify common functional groups in organic molecules • Interpret basic UV, IR, and ¹H NMR spectra to determine the structure of a simple organic molecule 	3
Unit 3:		
Natural products chemistry	<ul style="list-style-type: none"> • Describe the fundamental structures and classifications of major natural products, including alkaloids, steroids, carbohydrates, amino acids, and nucleic acids • Describe the chemical properties and synthetic applications of different classes of natural products 	6
Unit 4:		
Aromatic and heterocyclic chemistry	<ul style="list-style-type: none"> • Describe the concept of aromaticity and the properties of aromatic and heterocyclic compounds • Predict the products of electrophilic and nucleophilic aromatic substitution reactions 	5
Section B: Inorganic Chemistry for Nuclear Medicine		
Unit 5:		

Classification of elements and periodicity in properties	<ul style="list-style-type: none"> • Explain the organization of the periodic table and the principles of periodicity and Aufbau's principle • Compare and contrast the trends of atomic, covalent, and ionic radii, ionization enthalpy, electron gain enthalpy, and electronegativity across periods and down groups • Explain the influence of effective nuclear charge on these periodic properties • Describe the electronic configurations of diatomic molecules of first and second-row elements 	6
Unit 6:		
Extractions of metals & chemical bonding and shapes of molecules	<ul style="list-style-type: none"> • Describe the general methods for isolating and purifying metals in d-block elements (Technetium, Gallium, Gold, Silver, and Copper etc.) • Explain the principles and applications of the Ellingham diagram in metallurgy • Explain the principles of ionic and covalent bonding, including concepts like the Born-Haber cycle, Fajan's rules, and Valence Bond Theory • Use Born-Landé equation & Kapustinskii expression to calculate lattice energy 	5

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 7:		
Main group elements (s and p blocks)	<ul style="list-style-type: none"> • Explain the reactions of alkali and alkaline earth metals with oxygen, hydrogen, and water • Understand the properties of main group elements within a group, including the concept of the inert pair effect • Describe the synthesis, structure, and properties of important compounds like diborane, ammonia, and silane • Explain the synthesis and reactions of oxoacids and halides of various elements 	5
Unit 8:		
Transition metals (d block)	<ul style="list-style-type: none"> • Describe the general characteristics of d-block elements • Explain the structure, isomerism, and electronic spectra of coordination complexes using theoretical approaches like VB, MO, and Crystal Field Theory • Understand the structure, color, and magnetic properties of metal complexes using different theoretical models • Describe the structure and bonding in organometallic compounds like metal carbonyls and metallocenes • Explain the mechanism of homogeneous catalysis using Wilkinson's catalyst 	6
UNIT 9:		

Analytical chemistry	<ul style="list-style-type: none"> • Explain the fundamental principles of qualitative and quantitative analysis • Understand the various titrations, including acid base, oxidation-reduction, and complex metric titrations. • Describe the use and types of indicators in chemical analysis 	4
Main Reference:	<ul style="list-style-type: none"> • Graham Solomon, T.W., Fryhle, C.B. & Snyder, S.A. Organic Chemistry, John Wiley & Sons (2014). • McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013. • Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988). • Eliel, E.L. Stereochemistry of Carbon Compounds, Tata McGraw Hill education, 2000. • Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S. • Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010 • Morrison, R. N. & Boyd, R. N., Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). • Rodger, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Edition, 2002. • Shriver, D. E. & Atkins, P. W., Inorganic Chemistry, Oxford University Press, 5th Edition. Huheey, J. E., Keiter, E. A., & Keiter, R. L., Inorganic Chemistry – Principles of Structure and Reactivity, Pearson Education, 4th Edition, 2002. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, ACS Publications, 1962. • Rodger, G.E. Inorganic and Solid State Chemistry, Cengage Learning India Edition, 2002 • Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wile 	
Additional References	<ul style="list-style-type: none"> • March, J., Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, Wiley, 4th Edition, 1992. • Morrison, R. N. & Boyd, R. N., Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). • Finar, I. L., Organic Chemistry, Volumes 1 and 2, Pearson Education. • Das, Asim K., Fundamentals of Inorganic Chemistry, Vol. II, CBS Publications, 2nd Edition, 2010. • Pradeep's, Inorganic Chemistry, Vol. I & II, Universal Book Seller, 14th Edition, 2017. 	

BNM1203 – RADIATION PHYSICS

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Modern physics and Introduction to radiation physics		
Modern physics	<ul style="list-style-type: none"> • Define inertial frames and explain Galilean invariance • State the postulates of special relativity • Describe Lorentz transformations and their significance • Apply relativistic velocity addition theorem and explain mass-energy equivalence • Analyze problems involving Lorentz transformations and relativistic velocity addition • Describe Bohr’s and Rutherford’s atomic models • Explain the production of X-rays • Outline the X-ray diffraction process • Explain wave-particle duality and wave properties of matter • Describe de Broglie waves and the uncertainty principle • Recall the basics of the Schrödinger equation • List particle properties of waves and different types of electromagnetic waves • Explain the working principle of the electron microscope • Analyze how electron microscope uses wave and particle concepts for imaging 	8
General properties of nuclei	<ul style="list-style-type: none"> • Discuss the composition of the atomic nucleus and intrinsic properties such as mass, radius, matter density, and charge density • Explain nuclear stability, binding energy, and the fate of unstable nuclei • Describe radioactivity and the different decay modes: beta emission, beta-gamma emission, isomeric transition/internal conversion, electron capture-gamma emission, positron-gamma decay, alpha emission • List properties of alpha, beta, gamma particles, positrons, neutrons, and X-rays • Explain the beta decay spectrum • Define radioactivity, decay constant, and list units of radioactivity • State laws of radioactivity • Derive and analyze the radioactivity decay equation • Define, derive, apply, and analyze the radioactive half life concept • Explain specific activity and apply its concept in nuclear medicine contexts • Explain decay of mixed radionuclide samples and apply this knowledge in nuclear medicine scenarios • Explain parent-daughter decay relationships • Describe N/A plot, nuclear stability curve, and separation energy • Explain nuclear spin, parity, magnetic moments, and electric moments • Discuss nuclear excited states and transitions 	20

CONTENT	COMPETENCIES	NO. OF HOURS
Nuclear models	<ul style="list-style-type: none"> • Describe the liquid drop model, its assumptions, and explain the semi-empirical mass formula • Explain the Fermi gas model including degenerate fermion gas and symmetry potential • Describe the shell model: evidence for shell structure, magic numbers, mean field, and residual interactions • Explain basic characteristics of nuclear forces and provide an overview of meson theory • Analyze how these models explain nuclear properties and phenomena 	8
Unit 2: Nuclear Reactions and Interaction of radiation with matter		
Nuclear reactions and production of radionuclides	<ul style="list-style-type: none"> • Illustrate nuclear reactions, nuclear energy levels, nuclear isomers, and bombardment processes • Explain nuclear fission and fusion reactions and their differences • List various types of nuclear reactors, including breeder reactors • Illustrate design features of nuclear reactors • List different types of medical cyclotrons • illustrate design of nuclear reactors 	8

Interaction of Radiation with matter	<ul style="list-style-type: none"> • Define black body radiation and explain its significance • Explain interaction of charged particles with matter including collisional and radiative losses • Describe charged particle tracks and their characteristics • Define the Cerenkov effect • Explain the photoelectric effect • Apply photoelectric effect to problems, and analyze its outcomes • Explain Compton scattering • Apply it, and analyze scattering results • Explain pair production • Describe energy loss mechanisms of electrons and positrons • Explain Bremsstrahlung radiation processes • Define coherent scattering • Explain the importance of radiation attenuation in radiology and nuclear medicine • Describe transmission of high-energy radiation through matter, including Linear Energy Transfer (LET) • Explain linear and mass attenuation coefficients and interpret cross-section curves with respect to gamma energy and atomic number • Apply linear and mass attenuation coefficients in nuclear medicine contexts • Describe the positron annihilation process • Explain heavy charged particles' stopping power, range, and the Bethe-Bloch formula • Discuss neutron interactions with matter, including scattering and absorption 	16
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CONTENT	COMPETENCIES	NO. OF HOURS
Main Reference:	<ol style="list-style-type: none"> 1. Concepts of Modern Physics – Arthur Beiser 2. Nuclear Medicine Physics – Ramesh Chandra 3. Physics in Nuclear Medicine – Simon Cherry, 4. Physics in Nuclear Medicine- Sorenson 5. Nuclear Medicine Physics- Ramesh Chandra 	
Additional References	<ol style="list-style-type: none"> 1. Essential Nuclear medicine Physics- Rachel A. Powsner, Edward R. Powsner 2. Introductory Nuclear Physics- Krane K. S. 3. Radiation Detection and Measurement- Knoll G. F. 	

BNM1204 – FUNDAMENTALS OF ELECTROMAGNETISM IN NUCLEAR MEDICINE

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1:		
Fundamentals of Electricity	<ul style="list-style-type: none"> • State Coulomb’s law and explain the concept of electric field and electric potential • Explain Gauss’s law and apply electrostatic boundary conditions • Solve Laplace’s equation for simple boundary conditions • Describe capacitors, linear dielectrics, and dielectric polarization • Explain volume and surface bound charges and electrostatic energy • State Biot-Savart law and Ampere’s law • Explain Faraday’s law of electromagnetic induction and self and mutual inductance 	7
Capacitance, Inductance and AC circuits	<ul style="list-style-type: none"> • Describe alternating currents (AC), and simple DC and AC circuits with resistors, inductors, and capacitors (R, L, C) • Explain displacement current, impedance in RC, RL, RLC circuits, resonance, and quality factor Q • Analyze power in AC circuits: real, reactive, apparent power, and power factor • Describe transformers (ideal and real), efficiency, and isolation • Explain electrical safety concepts including shock hazards, grounding, insulation, and isolation in medical systems • Describe circuit protection devices such as fuses and circuit breakers • Apply electrical safety principles in Nuclear Medicine settings, including power supply safety in imaging rooms and reducing electrical artifacts 	8
Unit 2: Magnetism		

<p>Magnetic fields and electromagnetic concepts.</p>	<ul style="list-style-type: none"> • Define magnetic fields, including magnetic flux and field lines • Explain the motion of charged particles in magnetic fields via Lorentz force and cyclotron motion • Describe different magnetic properties of materials: diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic, ferrimagnetic • Analyze magnetization curves including hysteresis loop, coercivity, retentivity, and energy loss • Explain electromagnetic induction using Faraday's law and Lenz's law • Derive and apply the formula for induced emf • Analyze the direction of induced emf and current using Lenz's law and understand its relation to conservation of energy • Describe self-inductance, mutual inductance, eddy currents, and their suppression • State Maxwell's equations and explain plane electromagnetic waves and related concepts such as the Poynting vector and Poynting's theorem • Explain reflection and refraction at dielectric interfaces and calculate transmission and reflection coefficients at normal incidence 	<p>30</p>
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CONTENT	COMPETENCIES
	<ul style="list-style-type: none"> • Apply Lorentz force to describe motion of charged particles in combined electric and magnetic fields • Discuss applications in Nuclear Medicine including MRI magnetism, magnetic shielding, and inductance use in electronics
Main Reference:	<ol style="list-style-type: none"> 1. Sehgal, Chopra & Sehgal, Electricity & Magnetism 2. D.C. Tayal, Electricity & Magnetism 3. S.P. Taneja, Electricity & Magnetism (Hons) 4. R. Murugesan, Electricity & Magnetism
Additional References	<ol style="list-style-type: none"> 1. K.K. Tewari, Electricity & Magnetism with Electronics S. Chand 2. Brij Lal & N. Subrahmanyam, Electricity & Magnetism 3. Griffiths, Introduction to Electrodynamics 4. Purcell & Morin, Electricity and Magnetism

BNM1205 – PRACTICUM - II

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Cell Biology and Molecular Biology		
Cell and Molecular Biology Practical	<ul style="list-style-type: none"> • To study different part of light microscope and their use • To observe cheek cells under dark and bright field microscopy • To demonstrate the microscopic organization of tissues using light microscopy • To demonstrate total leukocyte counting in blood sample using hemocytometer • To demonstrate total Red blood cell counting in blood sample using hemocytometer • To prepare peripheral blood smear slide using wedge technique followed by May-GrunewaldGiemsa stained leukocytes under light microscope • To demonstrate osmotic fragility of RBC • To demonstrate liver function markers: ALT/AST and interpret • To perform lipid profile analysis, renal function tests • To study the process of mitosis in onion root tip cells or prepared slides and identify different stages • To demonstrate the effect of hypotonic and hypertonic solutions on red blood cell (RBC) morphology (crenation and hemolysis) • To demonstrate the technique of paper chromatography for the separation of amino acids or pigments • To observe and interpret common morphological abnormalities of red blood cells (RBCs) and white blood cells (WBCs) using pre-stained slides 	35
Unit 2: Biochemistry		
Biochemistry practical	<ul style="list-style-type: none"> • To perform qualitative tests for carbohydrates (Benedict's, Barfoed's, Molisch) • To estimate the amount of glucose using colorimetric method • To perform protein estimation using Lowry/Bradford method • To determine the absorption spectra of a biological sample with a colorimeter/ single/double beam spectrophotometer 	20
Unit 3: Electricity and Magnetism		
Electricity and Magnetism	<ul style="list-style-type: none"> • To construct and demonstrate the working of RC and RLC circuits • To determine self-inductance in coils • To measure magnetic field in solenoids • To verify the three Faraday's laws using magnets and coils. • To apply Thevenin's, Norton's, and Superposition theorems in circuit analysis 	20
Unit 4: Applied chemistry: Organic Chemistry & Inorganic chemistry for Nuclear Medicine		

Applied chemistry: Organic Chemistry & Inorganic chemistry for Nuclear Medicine practical	<ul style="list-style-type: none"> • Determine melting and boiling points of organic compounds • Identify functional groups through chemical tests • Prepare an organic compound, such as an ester, by reacting a carboxylic acid with an alcohol under acidic conditions and isolate the product • Study the reaction kinetics of organic reactions by measuring concentration changes over time and analyzing the rate and order of the reactions • Estimation of phenol and aniline by bromination method • To calibrate burette, pipette and volumetric flask using gravimetric method 	30
CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • To determine metal ions by gravimetric analysis through precipitation and weighing • To prepare and analyze coordination complexes by synthesizing metal–ligand compounds and studying their properties • To determine the amount of iodine liberated from a compound using redox titration 	
Main Reference	<p>Laboratory Manual of Cell and Molecular Biology by K.V. Chaitanya / PHI Learning</p> <p>Molecular Biology Techniques: A Laboratory Manual by S. Ignacimuthu / Narosa Publishing House</p> <p>IIT Roorkee Teaching Laboratories, Prof. Moumita Mait, Smt. Meena Kothyar</p> <p>Elements of Electromagnetics: M.N.O.sadiku (Oxford University Press)</p> <p>Textbook of Practical Organic Chemistry" (5th Edition) by A. I. Vogel et al.,</p> <p>Vogel's Textbook of Practical Organic Chemistry" by A.I. Vogel</p> <p>Organic Chemistry" by Paula Yurkanis Bruice</p> <p>Molecular Cell Biology by Darnell, Lodish, Baltimore, Scientific American Books 1990</p> <p>Plummer. D.T. (2004). An introduction to practical biochemistry. New Delhi: Tata McGraw Hill Publishers Co.</p>	
Additional References	<ol style="list-style-type: none"> 1. Molecular Cell Biology by Darnell, Lodish, Baltimore, Scientific American Books 1990 2. Raj K. Bansal's "Laboratory Manual of Organic Chemistry" (2025 edition), and typical organic practical manuals 3. Principles and Techniques of Biochemistry and Molecular Biology by Keith Wilson and John Walker 	

BNM1205 – CLINICAL PRACTICE - I

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
	• To understand the principles and observe the practices in hospital radio pharmacy	35
	• To understand the principles and observe the practices in in-vitro Nuclear Medicine	24
Unit 2		
	• To understand the principles and observe the practices in SPECT Scintigraphy	36
	• To understand the principles and observe the practices in radiation therapy	14
Main Reference	1. Quality control of Nuclear Medicine instruments - Tecdoc 602 2. Nuclear Medicine – The Requisites by Harvey A. Ziessman, Janis P. O'Malley, James H. Thrall	
Additional References	1. Radiopharmaceuticals in Nuclear Medicine by Kowalsky, Richard J., and Steven W. Falen 2. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai	

BNM2301 – FUNDAMENTALS OF IMMUNOLOGY AND MICROBIOLOGY

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Introduction to Microbiology and Microscopy		
	<ul style="list-style-type: none"> • To understand the history of Microbiology, Koch postulates, discovery of antibiotics • Explain the morphology of bacteria, viruses and fungi with major emphasis on bacterial structure • What is gram positive and gram negative bacteria • Explain the principle of microscopy: Bright field, dark field, phase contrast, fluorescent, electron microscopy 	10
Unit 2: Microorganism Growth and Interaction		
	<ul style="list-style-type: none"> • What are the phases of microbial growth • List the physical and chemical agents to kill microbes • Explain sterilization and pasteurization processes • What is the normal microflora in humans/ animals • What are the types of microbial pathogens and overview of diseases caused by them • Explain microbial interactions like symbiosis and antibiosis • Explain the host defense mechanism against pathogens 	10
Unit 3: Introduction to Immune System		
	<ul style="list-style-type: none"> • Overviews of immune system – Historical perspectives • What is innate and acquired immunity • What is clonal nature of immune response • Explain cells of the immune system: Hematopoiesis and differentiation, lymphocyte trafficking, B- lymphocytes, T lymphocytes, macrophages, dendritic cells, Natural killer cells and lymphocyte activated killer cells, eosinophils, neutrophils & mast cells • Describe Primary and secondary lymphoid organs, systemic function of immune system • Elucidate Antigen-Immunogenicity Vs. antigenicity, factors affecting immunogenicity, nature of immunogen, epitopes, heptans and antigenicity, pattern recognition receptors 	10
Unit 4: Antibody and Antigen-Antibody Reactions		

	<ul style="list-style-type: none"> • Explain Immunoglobulins: Structure of antibody, antibody effector function, antibody classes and biological activities, antigenic determinants on Immunoglobulins, Immunoglobulins superfamilies • Understand the overview of hybridoma technology: Production of Monoclonal Antibodies, applications of polyclonal and monoclonal antibodies • Explain vaccines and immunization • Explain Antigen–Antibody interactions: Strength of interaction, cross reactivity, antibody affinity, avidity • What is precipitation and agglutination reactions • Explain immunodiffusion, immunoelectrophoresis, immunoassays, Enzyme linked immunosorbent assay (ELISA), Radioimmunoassay (RIA), western blot, Immunofluorescence 	15
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CONTENT	COMPETENCIES	NO. OF HOURS
Main Reference:	<ol style="list-style-type: none"> 1. Janis Kuby, Immunology, 5th Edition 2. Ivan Roitt, Essential Immunology, 9th Edn. 3. Mary S. Leffell, and Noel R. Rose, Handbook of Human Immunology, CRC press 4. Tizzard, Immunology 4. Elgert Immunology 5. Lidyard, Instant notes in Immunology, 2nd Edition. 6. A handbook of practical and clinical immunology. Talwar GP and Gupta SK (1992) CBS Publication 	

BNM2302 – INTRODUCTION TO RADIO PHARMACY

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
General Introduction	<ul style="list-style-type: none"> • Explain radio pharmacy as a subject, Practice, and Laboratory • Name basic radio-pharmacy Laboratory equipment, TLC Scanner, Fume Hood, Laminar Flow hood Balance, Centrifuge, Autoclave etc. and their applications in radio pharmacy laboratory 	2
Unit 2		
Radionuclides in Nuclear Medicine and General Laboratory safety	<ul style="list-style-type: none"> • What are the Physical and chemical Characteristics of radionuclides and Application in Nuclear Medicine • Explain Safety considerations in radio- pharmacy laboratory such as Electrical safety, chemical safety, Fire safety, Radiation safety, Biological safety • Make use of standard Radiation handling procedures: Receipt - storage - disposal of radioactive materials, International symbols of radioactivity labels 	8
Unit 3		
Design, Plan layout and setting up of Radio pharmacy Lab	<ul style="list-style-type: none"> • How to Classify Radio different type radio pharmacy Laboratories • Compare Operational Concept, design and Plan layout of Radio pharmacy Laboratory, Hospital Radio pharmacy and Centralized Radio pharmacy • Outline setting up of a typical Hospital radio pharmacy laboratory • Outline Role and responsibility of Staff in Hospital Radio pharmacy and Central Radio pharmacy 	7
Unit 4		
Production techniques for Radionuclides	<ul style="list-style-type: none"> • What are the methods of Artificial Production of Radionuclides - Primary (Nuclear reactors & Accelerators) and Secondary Sources (RN generators) • Explain Design, construction and working principle of typical nuclear reactor and medical cyclotron and radionuclide generator • Explain Factors affecting Production Yield • What are the different types of radionuclide generators • Outline Ideal characteristics of generator system • Compare radiation characteristics of generator produced radionuclides • Explain Performance parameters for radionuclide generators 	13
Unit 5		

Radio pharmaceuticals: Cold kit Manufacture, labeling and Quality control	<ul style="list-style-type: none"> • Classify- Diagnostic and Therapeutic Radiopharmaceuticals in Nuclear medicine • Outline Ideal Characteristics of Radiopharmaceuticals • Explain principles of Radio-labelling techniques: Radio labelling, various methods of Radio-labelling- Direct & Indirect Labelling, factors affecting labeling efficiency • Explain mechanism of localization of Radiopharmaceuticals • Explain Cold Kits production and role of contents in labeling process • Physical, pH quality checks • Radionuclides Purity (RNP), Radiochemical Purity (RCP), • Particle size and number 	15
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CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • Sterility, Pyrogenicity • Bio-distribution studies. 	
Main Reference:	<ol style="list-style-type: none"> 1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen 2. Fundamentals of Nuclear Pharmacy, 3rd Edition Gopal B Saha 	
Additional References	<ol style="list-style-type: none"> 1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT 2. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai 3. Hand Book of Radiopharmaceuticals Mohan H Patel 	

BNM2303 – NUCLEAR MEDICINE INSTRUMENTATION PHYSICS

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1:		
Radiation detection and Measurement	<ul style="list-style-type: none"> • Units of radiation exposure • Different types of radiation detectors • Principle of radiation detection by Gas filled detectors • Principle of radiation detection by inorganic scintillator detectors • Principle of radiation detection by organic scintillator detectors • Principle of radiation detection by semiconductor detectors 	4
Unit 2		
Dose Calibrators and Well Counters	<ul style="list-style-type: none"> • Principle of ionization chamber-based dose calibrators and their role in measuring radiopharmaceutical activity • Detailed components: pressurized chamber, electrometer, amplifier, digital display • Importance of geometry, energy dependence, and shielding in activity measurements • Calibration techniques using standard sources, reproducibility and linearity testing • Routine quality control checks: constancy, accuracy, precision, linearity, geometry dependence • Well counters: structure and function of NaI (Tl) crystal and PMT system • Use of lead shielding, pulse height analyzer settings, and background correction • Clinical applications: thyroid uptake measurement, blood volume studies, RIA/IRMA counting procedures 	2
Unit 3		
Gamma Ray Spectrometer	<ul style="list-style-type: none"> • Explain basic principles of scintillation detectors • Explain basic principle and working of photomultiplier tube • Explain basic principle and working of photodiodes • Explain composition and some examples of Inorganic scintillators • Explain working of Inorganic scintillators • Explain Ideal characteristics of inorganic scintillators • Explain types of amplifiers used in GRS • Explain working of amplifiers • Explain working of pulse height analyser and coincidence circuit • Explain working of semiconductor detectors • Explain basic principle and working of Avalanche photodiodes 	17
Unit 4		

Radiation Survey and Monitoring Instruments	<ul style="list-style-type: none"> • Classification and comparison of radiation survey instruments: GM counter, ion chamber, scintillation survey meter • Detection principles: voltage range, dead time, efficiency, and energy response • Instrument construction, electronics, and readout mechanisms • Area monitoring systems: wall-mounted and portable monitors in NM hot labs and imaging rooms • Personal monitoring devices: film badges, TLDs, OSLDs, and electronic dosimeters 	5
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CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • Contamination monitors for hand and surface swipes; protocols for assessment and decontamination • Regulatory framework: AERB dose limits, zone classification, and monitoring record maintenance • Applications in daily NM operations: source transport, radiopharmaceutical handling, spill response 	
Unit 5		
Gamma Probes in Nuclear Medicine	<ul style="list-style-type: none"> • Explain working of a multichannel analyser • Explain basic design of thyroid uptake probe • Explain Iso-response curve • Explain Quality control procedures • Explain basic Components of gamma probe • Explain Instrument design and working of gamma probe • Explain basic Applications of gamma probe • Explain basic Quality control of gamma probe 	11
Unit 6		
Liquid Scintillation and Whole Body Counters	<ul style="list-style-type: none"> • Explain the Importance and need of liquid scintillation counting • Explain the Principle of liquid scintillation counting • Explain the Instrument design and working of liquid scintillation counter • Explain the Quenching and Quench correction methods • Explain the Applications of liquid scintillation counting and Quality control of liquid scintillation counter • Explain the whole body counters working principle and instrumentation • Explain the Application of whole body counters, Quality control and applications 	12
Unit 7		

Rectilinear scanners and Gamma camera	<ul style="list-style-type: none"> • List Historical importance of rectilinear scanner • Explain the Working principle and instrument design of rectilinear scanners • Explain the drawbacks of rectilinear scanners • Explain the Introduction to gamma camera • Explain the Components of gamma camera • Explain the Detector system and event localization • Explain the Collimators and Performance characteristics of parallel hole collimators • Explain the Events in gamma camera • Explain Types of gamma camera and their use • Explain the Performance characteristics of a gamma camera • Explain Artifacts in gamma imaging • Explain the Correction methods in gamma imaging • Explain Gamma camera performance measurement-Spatial Resolution • Explain Gamma camera performance measurement-Energy Resolution and sensitivity • Explain Gamma camera performance measurement-Image uniformity and counting rate 	20
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CONTENT	COMPETENCIES	NO. OF HOURS
Main Reference:	<ol style="list-style-type: none"> 1. Physics in Nuclear Medicine- Sorenson 2. Quality control of Nuclear Medicine instruments- Tecdoc-602 3. Radiation Detection and Measurement- Knoll G.F. 	
Additional References	<ol style="list-style-type: none"> 1. Mosby's Manual of Nuclear Medicine Procedures- D.Brucee Sodes, Paul J Early 2. Nuclear Medicine-Robert E. Henkin, Mark A. Boles 3. Computers in Nuclear Medicine-Lee Kai Hi 	

BNM2304 – PRINCIPLES OF WAVES AND OPTICAL PHYSICS IN BIOMEDICAL IMAGING

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1 : Oscillations		
Oscillators and their application in Nuclear Medicine	<ul style="list-style-type: none"> • Define oscillations and periodic motion and give examples from mechanical (spring–mass, pendulum) and electrical (LC circuit) systems • Explain key terms related to SHM: amplitude, frequency, time period, and phase • State and solve the differential equation for a simple harmonic oscillator and write its general solution • Explain the restoring force concept using Hooke’s law and relate it to SHM • Describe the mathematical form of SHM and the physical significance of angular frequency • Analyze the superposition of two or more simple harmonic oscillators • Explain Lissajous figures and interpret their shapes from combined oscillations • Define damped and forced oscillations; explain resonance, condition for resonance, and amplitude response curve • Explain the sharpness of resonance and the quality factor (Q factor) • Discuss applications oscillators in signal timing, synchronization and frequency selection in Gamma camera, PET scanners etc. 	10
Unit 2 : Waves		
Wave equations and energy dynamics of waves	<ul style="list-style-type: none"> • Define types of waves: mechanical (requiring medium) versus electromagnetic (can propagate in vacuum), and classify transverse versus longitudinal waves • Explain fundamental wave parameters: wavelength, frequency, wave number, amplitude, phase • State and solve the general wave equation • Describe characteristics of traveling and standing waves in one dimension • Explain energy density and energy transmission mechanisms in waves • Define group velocity and phase velocity and distinguish between them • Describe sound waves propagating through different media • Explain the Doppler Effect and its implications • State and explain Fermat’s Principle of least time in wave propagation • Application of Fermat’s Principle in scintillation imaging systems (PET, gamma cameras) 	15
Unit 3: Optics		

Optical properties of electromagnetic waves	<ul style="list-style-type: none"> • Describe the general theory of image formation • Explain wave-particle duality and electromagnetic wave theory as applicable to light • Describe interference of light and explain optical path retardation • Explain Fraunhofer diffraction: single-slit, double slit, and diffraction grating including angular width • Explain the Rayleigh criterion and resolving power of optical systems 	20
CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • Describe diffraction gratings and their applications • Explain polarization: linear, circular, and elliptic types • Explain total internal reflection • Application of total internal reflection in light guides for imaging cameras • Describe double refraction, optical rotation, optical activity, and birefringence • Discuss applications in Nuclear Medicine: light transport in scintillators, optical coupling in block detectors, and the use of lasers for collimation and alignment 	
Main Reference:	<ol style="list-style-type: none"> 1. Waves and Oscillations (Brij Lal & Subrahmanyam) Vikas Publishing 2. Oscillations and Waves (Garg, Ghosh, Gupta) PHI Learning 3. Waves & Optics (A.B. Gupta) 	
Additional References	<ol style="list-style-type: none"> 1. Waves & Optics (Avadhanulu & Arun Murthy) S. Chand 2. Oscillations, Waves, Acoustics (P.K. Mittal) 3. Vibrations and Waves (A.P. French) 4. Physics of Oscillations and Waves (N.K. Bajaj) 	

BNM2305 – PRACTICUM - III

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Radio pharmacy		
Radiopharmacy practical	<ul style="list-style-type: none"> • To check functioning of fume hood • To demonstrate Radioactive storage and disposal • To demonstrate PH measurement of given sample • To prepare Buffer solutions • To demonstrate separation of 99mTc with Organic Solvent extraction method • To demonstrate elution and calculation of elution efficiency of 99mTc from Column generator • To demonstrate Sterilization of Sodium pertechnetate • To demonstrate Parent Daughter decay Growth Relationship in Technetium generator • To demonstrate Molybdenum Breakthrough Assay of Sodium Pertechnetate • To demonstrate Aluminium Breakthrough Assay of Sodium Pertechnetate • To illustrate Radiochemical Purity of Sodium Pertechnetate by Paper Chromatography • To preparation 99mTc labelled DTPA, MDP, Mebrofenin • To preparation 99mTc labelled, ECD, EC, Sulphur Colloid, MIBI • To perform Quality control of 99mTc labelled Radiopharmaceuticals. • To learn dispensing and administration techniques for 99mTc-Radiopharmaceuticals for patients 	40
Unit 2: Nuclear Medicine Instrumentation		

Nuclear Medicine Instrumentati on practical		<ul style="list-style-type: none"> • To perform quality control of dose calibrator • To determine the operational characteristics of GM counter • To compare the dead time of GM counter for different radioactive sources • To perform energy calibration of gamma ray spectrometer • To demonstrate the role of linear amplifier in pulse shaping and amplification of pulse received from photomultiplier tube and preamplifier in a Gamma ray spectrometer • To demonstrate energy linearity of gamma ray spectrometer using different radioisotopes • To identify unknown radionuclide using gamma ray spectrometer • To determine activity of given radioisotope using gamma ray spectrometer • To perform thyroid uptake study • To demonstrate human ECG recording and analyze it for QRS voltage and frequency • To perform ECG measurements and carry out manual electrical axis analysis 	28
Unit 3: Waves and Optics			
Unit 3: Waves and Optics experiments		<ul style="list-style-type: none"> • To calculate dispersive power of a prism • To verify Newton's formula for a lens separated by a distance experimentally • To set up fiber optics for basic transmission experiments • To measure propagation loss, bending loss, and numerical aperture in fiber optics • To demonstrate the working of fiber optic sensors and understand their application in endoscopy and medical imaging 	22
Main Reference		<ol style="list-style-type: none"> 1. Vogel's Textbook of Quantitative Chemical Analysis" by G.H. Jeffery et al. 2. Inorganic Chemistry Laboratory Manuals used in universities (e.g., CHEM 304 Inorganic Chemistry Lab Manual) that cover similar experimental procedures precisely. 3. "Practical Manual of Inorganic Chemistry" by Dr. Akhil Nagar et al., which gives practical procedures widely used in UG and PG laboratories. 4. Nuclear Medicine Technology & Techniques Third Ed Donald Bernier et.al 5. Physics in Nuclear Medicine, Sorenson 	

Additional References	<ol style="list-style-type: none"> 1. Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual" by Gregory S. Girolami, Thomas B. Rauchfuss, and Robert J. Angelici (University Science Books, 2. Mosby"s Manual of Nuclear Medicine Procedures, D.Brucee Sodee,Paul J Early 3. Quality control of Nuclear Medicine instruments, Tecdoc 602 1999) 	
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BNM2306 – CLINICAL PRACTICE - II

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Radio pharmacy Practices	<ul style="list-style-type: none"> • To observe the arrangement of Radio pharmacy lab for daily activities • To list and identify items in the stock inventory • To observe the QC of dose calibrator • To observe preparation and dispensing of radiopharmaceuticals • To observe the QC of radiopharmaceuticals • To observe patient preparations and practices as per regulatory guidelines 	30
Unit 2		
In-vitro Nuclear Medicine Practices	<ul style="list-style-type: none"> • To list and identify stock inventory • To list various non-imaging and radiation monitoring equipment • To observe radiation surveillance and generation of the reports 	24
Unit 3		
Scintigraphy Practices	<ul style="list-style-type: none"> • To observe the arrangement of imaging room for daily activities • To observe daily QC of imaging and other accessory devices • To observe patient preparations and practices as per regulatory guidelines 	24
Unit 4		
Radionuclide Therapy Practices	<ul style="list-style-type: none"> • To list and identify stock inventory • To observe the QC of dose calibrator • To observe & preparation and dispensing of therapeutic radiopharmaceuticals • To observe the QC of radiopharmaceuticals • To observe patient preparations and practices as per regulatory guidelines 	27

BNM2401 – RADIOCHEMISTRY

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1:		
Atomic and molecular structure	<ul style="list-style-type: none"> • Recall the fundamental principles of quantum mechanics, including Planck's black body radiation, the photoelectric effect, and Heisenberg's uncertainty principle • Recall the Schröd'inger wave equation for a simple system like a particle in a one dimensional box • Recall the principles of Pauli's Exclusion Principle and Hund's Rule of maximum multiplicity • Recall the significance of wave functions and their properties (normalized, orthogonal) • Draw the shapes of s, p, and d orbitals and explain their energy spectrum based on the radial and angular wave functions of the hydrogen atom 	6
Unit 2:		
Gaseous state	<ul style="list-style-type: none"> • State and mathematically express gas laws such as Boyle's law, Charles's law, Gay-Lussac's law, and Avogadro's law • State Dalton's law of partial pressures and explain its applications • State Graham's law of diffusion and its significance • Understand the concept of Gibbs free energy (ΔG) and its significance in predicting the spontaneity of chemical reactions under constant temperature and pressure • Describe the key concepts of the kinetic molecular model of gases, including collision frequency; mean free path, and viscosity • Understand the Maxwell-Boltzmann distribution of molecular velocities and explain its implications for heat capacities • Explain the ideal gas law and the reasons for deviations from ideal behaviour • Use the van der Waals equation to model the behaviour of real gases (Carbon dioxide and oxygen) • Describe the critical state and the law of corresponding states 	8
Unit 3:		
Liquid state	<ul style="list-style-type: none"> • Describe the physical properties of liquids, such as vapor pressure, surface tension, and viscosity • Explain how temperature and the concentration of solutes affect the surface tension and viscosity of a liquid • Use these concepts (such as viscosity, surface tension, compressibility, diffusion, and the molecular structure of liquids) to describe real world applications of liquid properties 	7
Unit 4:		

Solid state	<ul style="list-style-type: none"> • Describe the concept of unit cells, crystal systems, and Miller indices • Use Bragg's Law to solve problems related to X ray diffraction • Explain the crystal structures of common ionic and covalent solids like NaCl, CsCl, and diamond • Describe different types of crystal defects and their impact on material properties 	7
CONTENT	COMPETENCIES	NO. OF HOURS
Unit 5:		
Chemical thermodynamics	<ul style="list-style-type: none"> • Describe the fundamental laws of thermodynamics and the concepts of reversible and irreversible processes • Explain the properties of thermodynamic functions, including enthalpy, entropy, and Gibbs free energy • Solve problems related to thermochemistry and thermodynamic functions • Understand their dependence on composition using the Gibbs-Duhem equation • Explain the concept of chemical potential and its applications 	6
Unit 6:		
Chemical and phase equilibria	<ul style="list-style-type: none"> • Explain the law of mass action and the significance of equilibrium constants (K_p, K_c, etc.) • Interpret the effect of changes in temperature, pressure, or concentration on a system at equilibrium using the Le-Chatelier principle • Describe the concepts of solubility product and salt hydrolysis • Interpret acid-base titration curves and select appropriate indicators • Use Raoult's and Henry's laws to solve problems related to dilute solutions • Interpret single and two-component phase diagrams using the Gibbs phase rule 	7
Unit 7:		
Electrochemistry		
	<ul style="list-style-type: none"> • Explain the concepts of conductivity, molar conductivity, and ionic mobility • Use Kohlrausch's law and the Debye-Hückel Onsager equation to calculate conductivity and ionic velocities • Describe the principles of electrolysis and its industrial applications • Calculate the electromotive force (EMF) of a cell using the Nernst equation • Explain the concept of standard electrode potential and the electrochemical series • Use EMF measurements to perform potentiometric titrations 	6
Unit 8:		

Chemical kinetics	<ul style="list-style-type: none"> • Differentiate between the order and molecularity of a reaction • Solve integrated rate equations for zero, first, and second-order reactions • Apply the steady-state approximation to determine the rate law for complex reaction mechanisms • Explain the relationship between temperature and reaction rate using the Arrhenius equation • Describe the principles of collision theory and the mechanisms of catalysed reactions, including Michaelis-Menten kinetics 	6
Unit 9:		
Adsorption	<ul style="list-style-type: none"> • Define the types of adsorption (physisorption and chemisorption) • Explain the Gibbs adsorption equation and the concept of an adsorption isotherm • Adsorption isotherms with the help of appropriate examples 	4
Unit 10:		
Spectroscopy	<ul style="list-style-type: none"> • State the Beer-Lambert's law • Explain the fundamental principles of rotational, vibrational, electronic, and magnetic resonance spectroscopy 	4

CONTENT	COMPETENCIES	NO. OF HOURS
Main Reference:	<ul style="list-style-type: none"> • Puri, B. R., Sharma, L. R., & Pathania, M. S., Principles of Physical Chemistry, Vishal Publishing Co., 48th Edition, 2023. • Kapoor, K. L., A Textbook of Physical Chemistry (Volumes 1-5), Macmillan India, 4th Edition, 2011. • Madan, R. L., Physical Chemistry, McGraw Hill Education (India), Latest Edition. 	
Additional References	<ul style="list-style-type: none"> • Tandon, O. P., & Singh, A. S., A Textbook of Physical Chemistry (Vols. 1 & 2), G.R. Bathla & Sons, 25th Edition, 2025. • Bahadur, P., Physical Chemistry, Pragati Prakashan, Latest Edition. 	

BNM2402 – RADIOBIOLOGY

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1:		
Bio-molecular and Cellular Radiobiology	<ul style="list-style-type: none"> • Outline major events in radiation interaction with biological system • Explain radiation chemistry and formation of free radicals • Compare direct and indirect interaction of radiation • Explain radiation interaction with DNA and chromosomes • Explain radiation Geno toxicity assessment • Explain radiation Cell death mechanisms and interpret cell survival assays • Identify Factors affecting cell radio- sensitivity/ survival fraction/radio-resistance • Compare Stochastic and deterministic effects of radiation • Compare Acute and delayed effects of radiation • Compare Whole body and localized organ exposure 	18
Unit 2:		
Early radiation effects	<ul style="list-style-type: none"> • Apply the concept of Lethal dose • Explain acute radiation syndrome • Explain NVD syndrome • Summarize Central nervous system syndrome, radiation dose related pathological changes • Summarize Gastrointestinal syndrome, radiation Dose related pathological changes • Summarize Bone marrow syndrome, radiation dose related pathological changes 	13
Unit 3:		
Delayed radiation effects	<ul style="list-style-type: none"> • Explain and Identify Late deterministic effects • Explain and Identify Late stochastic effects • Explain Models for estimating radiation associated cancer risk 	5
Unit 4:		
Radio sensitizers and radio protectors	<ul style="list-style-type: none"> • Explain role of heat as radio-sensitizer • Explain role of antioxidants as radio- protectors 	4
Unit 5:		
Radiation effects on embryo	<ul style="list-style-type: none"> • What are the various phases of Embryo development? • Outline dose dependent Effects of prenatal irradiation • Compare and contrast radiation effects on animal and humans 	5
Main Reference:	<ol style="list-style-type: none"> 1. Radiation Biology and Physics- Paul F Wilson and Joel S Bedford 2. Radiobiology for the Radiologist –Eric J Hall, and Amato J Giaccia Uma Devi 	

Additional References	1. Biological assessment of Radiation Damage – Thomas. L, Walden. Jr and Nushin K 2. Radiation biology – Devi P .Uma, Nagarathnam A and Rao BSS	
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BNM2403 – BIOSTATISTICS

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Introductory Biostatistics		
Introduction to Biostatistics	<ul style="list-style-type: none"> • Define statistics and biostatistics • Describe the limitations and characteristics of biostatistics • Explain the role of statistics in health sciences 	3
Variables	<ul style="list-style-type: none"> • Summarize the types of variables with examples Distinguish between qualitative & quantitative with appropriate examples • Distinguish between continuous & discrete variables with appropriate examples 	
Scales of Measurement	<ul style="list-style-type: none"> • Describe nominal, ordinal, interval and ratio scale of measurement of variables with appropriate examples • Distinguish between the four scales of measurement 	
Unit 2: Descriptive Statistics		
Summarizing Data: Tabulation Methods	<ul style="list-style-type: none"> • Illustrate the qualitative, quantitative and chronological classification to tabulate and summarize data 	7
Summarizing Data: Graphical Methods	<ul style="list-style-type: none"> • Describe graphical methods to summarize data: Pie chart, Bar chart, Line Plot, Histogram, Frequency Curve and Frequency Polygon 	
Measures of Central Tendency	<ul style="list-style-type: none"> • Explain the concepts of Mean, Median, Mode • Explain the concepts of Quartiles and Percentiles 	
Measures of Dispersion	<ul style="list-style-type: none"> • Describe the concepts of Range, Inter-quartile range, Variance, Standard deviation and Coefficient of variation • Explain the concept of skewness and describe three types of skewness • Explain the concept of kurtosis and describe three types of kurtosis 	
Unit 3: Introduction to Probability and Normal Distribution		
Probability: An Introduction	<ul style="list-style-type: none"> • Define the relative frequency approach to probability 	3
Normal Distribution	<ul style="list-style-type: none"> • Explain the characteristics of normal distribution • Compute the area under the normal distribution curve 	
Unit 4: Sampling Methods		

Need for Sampling	<ul style="list-style-type: none"> • Explain the need for sampling and the advantages of sampling over complete enumeration • Explain sampling and non-sampling error • Define and distinguish probability and non- probability sampling methods 	3
Random Sampling Methods	<ul style="list-style-type: none"> • Explain the uses and situation of each sampling technique and mention merits and demerits 	
CONTENT	COMPETENCIES	
Non-random Sampling Methods	<ul style="list-style-type: none"> • Explain the uses and situation of each sampling technique and mention merits and demerits 	
Unit 5: Introduction to Correlation and Regression Analysis		
Correlation Analysis	<ul style="list-style-type: none"> • Define correlation and its properties • Explain types of correlation with diagrams and appropriate examples • Illustrate using scatter plot the different types of correlation • Explain the Pearson's correlation coefficient and outline its properties • Explain the Spearman's correlation coefficient and outline its properties 	4
Regression Analysis	<ul style="list-style-type: none"> • Distinguish between dependent and independent variables • Explain the simple linear regression model along with the assumptions involved • Identify the slope and intercept coefficient from the model • Predict the dependent variable from the model for a given set of independent variables 	
Unit 6: Testing of Significance		
Understanding population, sample, parameter and statistics, estimate and estimator	<ul style="list-style-type: none"> • Define and differentiate parameter and statistic with examples • Define the basic terms-population, sample, sampling, parameter, statistic, estimate and estimator, point estimate • Define and differentiate standard deviation and standard error 	8
Sampling distribution/ standard error	<ul style="list-style-type: none"> • Determine the sampling distribution/standard error of sample mean, sample proportion, difference between two means, difference between two proportions (Large sample approximation (CLT)) 	
Confidence Interval	<ul style="list-style-type: none"> • Construct and interpret confidence interval for mean, difference between two means, proportion, difference between two proportions (large sample approximation) 	
Unit 7: Testing of Hypothesis		

General procedure of testing of hypothesis	<ul style="list-style-type: none"> Define/explain with example the concept of null hypothesis, alternative hypothesis, type I and type II errors. Define level of significance, power of the test and p-value, one sided and two-sided test. 	6
Parametric test: Single mean test, difference between two means test, and paired t test.	<ul style="list-style-type: none"> Explain the differences, merits and demerits of parametric and non-parametric over parametric tests 	

CONTENT	COMPETENCIES	NO. OF HOURS
Non Parametric test: Chi square test, Mann-whitney test, Sign test	<ul style="list-style-type: none"> Give the situation for parametric and non-parametric tests 	
Main Reference:	<ol style="list-style-type: none"> Lwanga SK, Tye CY, Ayeni O. Teaching health statistics: lesson and seminar outlines. World Health Organization, Marketing and Dissemination, 1211 Geneva 27, Switzerland; 1999. Health research methodology: a guide for training in research methods. World Health Organization; 2001. Bonita R, Beaglehole R, Kjellström T. Basic epidemiology. World Health Organization; 2006. Campbell MJ, Swinscow TD. Statistics at square one. John Wiley & Sons; 2011. 	
Additional References	<ol style="list-style-type: none"> Daniel, W. W., and Cross, C. L. (2018). Biostatistics: a foundation for analysis in the health sciences. Wiley. Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International. Rosner, Bernard, (2010). Fundamentals of Biostatistics, 7th Edition, Duxbury Press. Peter Armitage, Geoffrey Berry, J. N. S. Matthews, (2002). Statistical Methods in Medical Research, 4th Edition, Blackwell. Wayne W. Daniel, (2004). Biostatistics_ A Foundation for Analysis in the Health Sciences, 8th Edition, Wiley Series in Probability and Statistics. 	

BNM2404 – HEALTH PHYSICS AND RADIATION SAFETY

CONTENT	COMPETENCIES	NO. OF HOURS
Radiation quantities and unit	Define <ul style="list-style-type: none"> • Activity (Becquerel /Curie) • Energy, exposure (C/kg/ Roentgen), • LET, • Charge particles equilibrium (CPE), • Linear and mass attenuation coefficient, • Mass stopping power, • Air kerma, • Terma, • Absorbed dose (Gray/ rad), • Radiation weighting factor (WR) • Tissue win factor • equivalent dose • effective dose • collective effective dose person SV • annual limit of intake Ali becquerel • derived air concentration DAC becquerel/m³ • personnel dose equivalent • committed dose 	2
Operational limits	<ul style="list-style-type: none"> • Introduction to neutral backgrounds radiation, tell the concept of occupational risk, optimization of patient dose • Explain on philosophy of radiation protection system of dose limitation ALARA dose limit to radiation workers general public dose constraint for comforter of patient. • Explain and list on AERB/ICRP recommendation 	3
Radiation detection and Measurement	<ul style="list-style-type: none"> • Explain on principle of radiation detection, various gas detector (ionization chamber proportional counter and GM counter), solid state detector (scintillator, semiconductor and Thermoluminescent Dosimeter (TLD) and liquid scintillation counting system. • Explain on nuclear counting statistics, confidence level of measurement • Explain radiation monitoring, direct reading device. • Explain on calibration and response of radiation monitoring instruments. 	4

Radiation hazard Evaluation and control	<ul style="list-style-type: none"> List on internal and external radiation hazard and their perspective, use of kV, mAs, filtration, screens, Image intensifiers Explain on evaluation and control of hazard due to external radiation, individual and workplace monitoring application of time, distance and shielding, specific gamma ray constant, external radiation monitoring, survey meters. Explain on internal hazard evaluation and control, protective measures for handling of unsealed source (e.g. fume hood, glove box), environment control, protective clothing. 	4
CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> Explain on contamination monitoring direct and indirect, air contamination monitoring, personal contamination monitoring and decontamination procedure surface decontamination procedure. 	
Radiation Dosimetry	<ul style="list-style-type: none"> Explain and derive single compartmental model and 2 compartmental model with and without back transference Explain in vivo dosimetry using classical dosimetry mechanism Explain <ul style="list-style-type: none"> Beta dosimetry Gamma dosimetry Geometrical factor explaining the Dosimetry of low energy electromagnetic radiation <ul style="list-style-type: none"> Explain and derive MIRD formulation Define cumulated activity equilibrium absorbed dose constant absorption factor specific absorption fraction <ul style="list-style-type: none"> Explain the doors reciprocity theorem Define mean dose per cumulated activity List the limitation of MIRD method what is extremity dosimetry 	5
Quality control (QC) in nuclear medicine	<ul style="list-style-type: none"> List the importance of QC in nuclear medicine. Explain on the test parameters and procedure of QC of isotopes calibrator, planer gamma camera system, SPECT Explain on test parameters and procedure for QC of PET, PET-CT and radio pharmaceuticals 	2
Radionuclide therapy radiation safety Aspect	<ul style="list-style-type: none"> List the various radio nuclei administration technique Explain and summarise on pre and post therapy precaution, nursing care, patient monitoring and discard criteria Explain on optimization of radiation dose to non-target tissue, radiation safety consideration in treatment of Ca-thyroid, palliative bone, metastases and other therapeutic procedures such as radiation synovectomy peptide therapy etc. 	2

Disposal of Radioactive waste	<ul style="list-style-type: none"> • Explain on origin and types of waste, classification of wastes and methods of disposal, disposal of short-lived solid, liquid and gaseous radioactive waste. (C2) • Explain on disposal of animal carcasses and radioactive foliage disposal limits for ground burial and sanitary sewage system incineration disposal of long-lived and indispersible radioactive waste 	3
Planning of nuclear medicine facilities	<ul style="list-style-type: none"> • Explain on classification and general features of NM laboratories (site, typical floor plans, ventilation, surface, walls, floor and ceiling, work surfaces, containment systems, fume-hood, glove box etc.) • Explain on planning of NM laboratories, such as diagnostic and high dose therapy, PET-CT and medical cyclotron installation, shielding evaluation of NM laboratories and medical cyclotron 	3
CONTENT	COMPETENCIES	NO. OF HOURS
	<ul style="list-style-type: none"> • Outline on model layouts of various NM laboratories, commissioning, decommissioning. 	
Transport of Radioactive material	<ul style="list-style-type: none"> • Explain on rules governing transport of radioactive material, introduction, terms used (e.g. Competent Authority, A1 & A2 values, Transport Index (TI) etc.), transport scenarios (routine, normal & accident), types of packages covered under the transport regulations, general requirement of all packaging, requirements for transport of radioactive material in liquid form, expected limit, special form and other than special form • Explain on TREMCARD, procedure for packing, marking, labelling transport documents responsibilities of consignor and consignee, consignor's declaration, instruction to the carrier, transport of surface contaminated objects, off-normal situations during transport of radioactive materials, handling off-normal situation, emergency planning. 	3
Radiation Accidents, Case Studies and lesson Learns	<ul style="list-style-type: none"> • Explains on radiation accidents involving radioisotopes, orphan and vulnerable sources, handling of emergency situations, resulting from spillage of radiopharmaceuticals/liquid radioisotopes, misadministration of radiopharmaceuticals and its consequences • Explain on general method of prevention of accident, loss of radioisotope fire accident and explosion; follow up action through emergency response plan, case study and mitigation lesson learned. 	3

Regulatory aspect of nuclear medicine facilities	<ul style="list-style-type: none"> • Explain on regulation with respect to nuclear medicine laboratory relevant regulatory documents such as act, rule, code, standards and Guides, responsibility of employer, licence, radiation safety officer RSO, technologists and radio isotope supplier safety and security of radioactive source during transport any storage inventory control • Explain on security provision: administrative and technical measures, graded approach in security provision, physical protection system, regulatory requirement for import/ export, procurement, use handling transfer and disposal of radioisotope inventory control, Radiation protection programme RPP e licensing procures in India 	2
Emergency response plan and preparedness	<ul style="list-style-type: none"> • List and explain on normal and potential exposure accident situation involving radioisotopes element of emergency planning and preparedness including procedure for notification and communication administrative and technical procedure emergency response accessories responsibilities of employer licence RSO technologists and radio isotope/equipment supplier in case of emergencies 	2
Main Reference:	1. Physics in Nuclear Medicine - Simon R. Cherry, James A. Sorenson, and Michael E	
Additional References	<ol style="list-style-type: none"> 1. Fundamentals of Nuclear Pharmacy, Fifth Edition- Gopal B. Saha, Ph.D. 2. Nuclear Medicine Therapy: Principles and Clinical Applications 3. By Aktolun, Cumali, Goldsmith, Stanley J. (Eds.) 4. Nuclear Medicine Physics: The Basics 8th Edition by Ramesh Chandra and Arman Rahmim, Wolters Kluwer Lippincott Williams and Wilkins 	

BNM2405 – PRACTICUM - IV

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1 : Radiobiology		
Radiobiology Practical	<ul style="list-style-type: none"> • To demonstrate the damaging effect of gamma and beta radiations on DNA • To demonstrate genotoxicity of various agents using micronucleus assay • To demonstrate chromosomal aberrations induced by various agents • To demonstrate effect of ionizing radiations on red blood cells 	15
Unit 2 : In Vitro Nuclear Medicine Techniques		
In vitro Nuclear Medicine techniques practical	<ul style="list-style-type: none"> • To perform sample collection, storage and centrifugation of biological samples • To perform the in vitro steps of radiolabeling (e.g., using ^{99m}Tc or ^{51}Cr) for procedures like mass or survival studies, and to evaluate the labeling efficiency • To perform RIA using kits • To perform IRMA (e.g., for a large protein hormone like TSH or hCG) and understand the direct relationship between antigen concentration and bound radioactivity • To measure the absorption of orally administered Vitamin B12 by Schillings test using ^{57}Co-B12 	20
Unit 3 : Health Physics and Radiation protection		
Health Physics and Radiation protection practical	<ul style="list-style-type: none"> • To perform radiation area survey • To perform radiation decontamination • To demonstrate the effect of time on radiation exposure • To demonstrate the effect of distance on radiation exposure • To demonstrate the effect of shielding on radiation exposure • To perform calibration of contamination Monitor using standard source(s) • To perform calibration of radiation survey meter using standard source(s) 	20
Unit 4 : Radiochemistry		
Health Physics and Radiation protection	<ul style="list-style-type: none"> • To determine the rate constant and order of a chemical reaction from concentration measurements • To measure physical properties of liquids (viscosity, surface tension, vapour pressure) and analyze the data • To determine the velocity constant and concentration effect for the second-order reaction $\text{KI} + \text{K}_2\text{S}_2\text{O}_8$ • To determine equilibrium constants of chemical reactions • To study pH versus volume curves in acid–base titrations • To determine the heat of solution of KNO_3 using solubility measurements 	20

<p>Main Reference</p>	<ol style="list-style-type: none"> 1. Nuclear Medicine Technology & Techniques Third Ed Donald Bernier et.al 2. Physics in Nuclear Medicine, Sorenson 3. "Physical Chemistry Lab Manual" for M.Sc. Chemistry Practical which covers kinetics, physical property measurements, and electrochemical studies. 4. American Chemical Society Guidelines on Measurement of Physical Properties. 5. "Physical Chemistry of Surfaces" by Arthur W. Adamson and Alice P. Gast, a resource focusing on adsorption and surface phenomena. 	
<p>Additional References</p>	<ol style="list-style-type: none"> 1. Mosby's Manual of Nuclear Medicine Procedures, D.Bruce Sodee, Paul J Early 2. Radioimmuno assay- Principles and Practice, Pillai & Bhandarkar 3. "Physical Chemistry Laboratory Manuals" by various universities, detailing viscosity, surface tension, vapor pressure, and phase diagrams measurements. 4. "Atkins' Physical Chemistry" by Peter Atkins and Julio de Paula, a comprehensive general physical chemistry textbook with strong treatment of kinetics and surface chemistry. 	

BNM2406 – CLINICAL PRACTICE - III

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Radiopharmacy Practices	<ul style="list-style-type: none"> • To arrange Radiopharmacy lab for daily activities • To identify and produce the inventory • To perform QC of dose calibrator • To prepare and dispense radiopharmaceuticals • To perform QC of radiopharmaceutical • To express procedures to patient and to practice as per regulatory guidelines • To write and maintain registers 	30
Unit 2		
In-vitro Nuclear Medicine Practices	<ul style="list-style-type: none"> • To locate and identify stock inventory • To maintain various non-imaging and radiation monitoring equipment • To perform radiation surveillance and produce the reports • To write and maintain registers 	30
Unit 3		
Scintigraphy Practices	<ul style="list-style-type: none"> • To arrange imaging room for daily activities • To perform daily QC of imaging and other accessory devices • To express procedures to patient and to practice as per regulatory guidelines • To write and maintain registers 	45
Unit 4		
Radionuclide Therapy Practices	<ul style="list-style-type: none"> • To locate and identify stock inventory • To practice QC of dose calibrator • To observe preparation and dispensing of therapeutic radiopharmaceuticals • To practice QC of radiopharmaceuticals • To express procedures to patient and to practice as per regulatory guidelines • To maintain radiation exposure records • To write and maintain registers 	30
Main Reference	<ol style="list-style-type: none"> 1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen 2. Nuclear Medicine-The Requisites: Harvey A. Ziessman, Janis P. O'Malley, James H. Thrall 	

Additional References	<ol style="list-style-type: none">1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT2. NUCLEAR MEDICINE FACILITIES, CODE NO. AERB/RF-MED/SC-2 (Rev. 2) or as revised from time to time by AERB Mumbai.3. Nuclear Medicine Technology: Procedures and Quick Reference – Pete Shackett	
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BNM3501 – RADIOPHARMACEUTICAL CHEMISTRY

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Iodine labelled radiopharmaceuticals	<ul style="list-style-type: none"> • Explain radio Iodine Chemistry • Describe the production, physical and chemical characteristics, biological behaviour of different isotopes of Iodine • Compare and identify merits and demerits of various radio-iodination methods • Describe synthesis, quality control and clinical applications of Iodine labelled radiopharmaceuticals 	11
99mTc-labelled Radiopharmaceuticals	<ul style="list-style-type: none"> • Explain Technetium Chemistry • Explain Labeling with 99mTc- Sodium pertechnetate • Outline Evolution of 99mTc-labelled Radiopharmaceuticals • Explain Coordination Chemistry of commonly used 99mTc-labelled Radiopharmaceuticals • Infer monographs for 99mTc-labelled Radiopharmaceuticals 	
Unit 2		
Radiopharmaceuticals for Positron emission tomography (PET)	<ul style="list-style-type: none"> • Describe the production of PET radionuclides • Describe the preparation method and quality control procedure for PET radiopharmaceuticals (F-18, C-11, N-13, O- 16, Ga-68) • Explain the clinical application and uptake mechanism • Outline the design, working and application of automated synthesis Modules • Outline the design and working of PET Radionuclide generators • Describe safe handling procedures of positron emitters 	17
Unit 3		
Therapeutic and theranostic Radiopharmaceuticals	<ul style="list-style-type: none"> • Illustrate targeted Radionuclide therapy and theranostics in nuclear medicine • Interpret the physical, chemical and biological characteristics of Therapeutic and theranostic radionuclides • Explain the therapeutic/theranostic clinical role and biological action mechanism of radio-pharmaceuticals 	14
Unit 4		

Regulatory guidelines for development of Radiopharmaceuticals	<ul style="list-style-type: none"> • Extend on general consideration for design of newer radiopharmaceuticals • Describe the development stages and drug terminology used in radiopharmaceutical development process • Summarize pharmacopeia for radiopharmaceuticals • Extend on Good Hospital Radio pharmacy Practices (GHRP) and Good Manufacturing Practices (GMP) for Radiopharmaceuticals • Outline the relationship between GMP & ISO relevant to nuclear medicine laboratory 	18
Unit 5: Regulatory guidelines for procurement, Safe handling and disposal of radioactive material		
	<ul style="list-style-type: none"> • Outline the E- Licensing procedures for handling Radioactive materials in India • Extend on regulation ethics and registration of radiopharmaceuticals 	

CONTENT	COMPETENCIES	NO. OF HOURS
	➤ Summarize the procedure and documentations for ordering, receiving, storage, decay and disposal of Radiopharmaceuticals	
Main Reference:	1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and 2. Nuclear Medicine, 2nd American Pharmacists Association, 2004, ISBN 1582120315 Kowalsky, Richard J., and Steven W. Falen, 3. Fundamentals of Nuclear Pharmacy, 3rd Edition Gopal B Saha	
Additional References	1. Sampson's Text Book of Radiopharmacy 4th Ed (Dec 2010), ISBN : 9780853697893 Edited by Theobald Tony 2. Hand Book of Radiopharmaceuticals by M H Patel	

BNM3502 – IMAGING INSTRUMENTS IN NUCLEAR MEDICINE

CONTENT	NO. OF HOURS	NO. OF HOURS
Unit 1		
Gamma Camera	<ul style="list-style-type: none"> • Explain the Introduction to gamma camera • Explain the Components of gamma camera • Explain the Detector system and event localization • Explain the Collimators and Performance characteristics of parallel hole collimators • Explain the Events in gamma camera • Explain Types of gamma camera and their use • Explain the Performance characteristics of a gamma camera 	15
Unit 2		
Single Photon Emission Tomography	<ul style="list-style-type: none"> • Introduction to SPECT • Design and working principle • Components of SPECT • Data acquisition • Performance characteristics , quality control aspects • SPECT artifacts 	15
Unit 3		
Positron Emission Tomography	<ul style="list-style-type: none"> • Introduction to PET, • Design, working principle • Components of PET • Data acquisition • Performance characteristics , quality control • Artifacts 	15
Main Reference:	<ol style="list-style-type: none"> 1. Nuclear Medicine the Requisites: Thrall James 2. Principles and Practice of Nuclear Medicine: P J Early, D.B Sodee 	
Additional References	<ol style="list-style-type: none"> 1. Nuclear Medicine in clinical diagnosis and treatment: Peter J Ell 2. Principles of Nuclear Medicine: Henry N.Wagner 3. Nuclear Medicine: Robert E.Henkin 	

BNM3503 – APPLICATIONS OF COMPUTER IN NUCLEAR MEDICINE

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Introduction to Computer Systems in NM	<ul style="list-style-type: none"> • Explain the function of key hardware components (CPU, memory, storage) and operating systems in image acquisition • What is Computer architecture (hardware, CPU, memory, storage) • Explain Operating systems (Windows/Linux basics) • What are Data types and its representation (binary, digital data) • What is the role of computers in nuclear medicine workflow 	5
Unit 2		
Digital Image Fundamentals	<ul style="list-style-type: none"> • What are Pixels • What are matrices • Explain spatial resolution • Define: bit depth, grayscale • Explain sampling and Quantization • what is Image file format (DICOM standards) 	5
Image Acquisition and Data Processing	<ul style="list-style-type: none"> • explain Analog-to-Digital Conversion (ADC) • what are Pulse Height Analyzer (PHA) integration • explain Frame-mode vs. List-mode acquisition • what is Uniformity 	5
Unit 3		
Image Processing Techniques	<ul style="list-style-type: none"> • Explain Image Display: Look-Up Tables (LUTs) • Explain Window/Level • what is Image Filtering: spatial vs. frequency domain • Explain smoothing (e.g., Butterworth, Hanning) • Explain noise reduction • What is edge detection 	5
Unit 4		
Image Reconstruction (SPECT and PET)	<ul style="list-style-type: none"> • Explain Backprojection and Filtered Backprojection – FBP • What is Iterative Reconstruction (e.g., OSEM) • What is Attenuation and Scatter Correction • What is Coincidence detection • Explain Sinogram • Explain FBP vs. Iterative methods in PET • What is Time-of-Flight (TOF) Corrections in PET 	10
Unit 5		

Quantitative Analysis and Kinetic Modeling	<ul style="list-style-type: none">• Explain Region of Interest (ROI) analysis• What is Time-Activity Curves (TACs) and Standardized Uptake Value (SUV) calculation and its limitations• Explain Basic kinetic models (e.g., two-compartment model)	5
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CONTENT	COMPETENCIES	NO. OF HOURS
Unit 6		
Network and Information Systems	<ul style="list-style-type: none"> • What is PACS: Architecture, components, workflow integration • Explain HIS/RIS integration with Nuclear Medicine systems. Networking basics (LAN, WAN, Teleradiology) 	5
Main Reference:	<ol style="list-style-type: none"> 1. Cherry, S. R., Sorenson, J. A., & Phelps, M. E. (2012). Physics in Nuclear Medicine (4th ed. or later). Elsevier. (Relevant chapters on instrumentation, computers, and imaging principles). 2. Vendor-specific software manuals for Nuclear Medicine workstations (e.g., GE Xeleris, Siemens syngo). 	
Additional References	<ol style="list-style-type: none"> 1. Selected articles and peer-reviewed journal publications as assigned by the instructor. 2. Dedicated nuclear medicine simulation software for image processing and reconstruction practice. 	

BNM3504 – CLINICAL NUCLEAR MEDICINE - I

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Endocrine System	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe pathophysiology of thyroid and parathyroid gland disorders • Elaborate on Thyroid imaging <ul style="list-style-type: none"> ➤ Dynamic and static thyroid scan ➤ Radiopharmaceuticals ➤ Imaging protocol/s, ➤ processing and scan interpretation • Elaborate on Thyroid uptake <ul style="list-style-type: none"> ➤ Radiopharmaceutical ➤ Procedure and calculation, ➤ Interpretation of uptake value • Elaborate on Parathyroid imaging <ul style="list-style-type: none"> ➤ Dual phase, dual isotope technique ➤ Radiopharmaceuticals ➤ Imaging protocol/s, ➤ processing and scan interpretation 	14
Unit 2		
Skeletal System	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe the skeletal tissue damage and systemic response bone remodeling process • Describe the general features of Infection and inflammation and acute and chronic inflammation • Describe the pathophysiology of bone metastatic tumors • Describe the pathophysiology of metabolic bone diseases • Describe the pathophysiology of bone metastatic tumors • Describe the pathophysiology of osteomyelitis • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for <ul style="list-style-type: none"> ➤ Whole body bone scan ➤ 3 phase bone scan ➤ Infection imaging 	17

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 3		
Gastrointestinal System	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe pathophysiology of esophageal disorders. • Describe pathophysiology of gastric disorders • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for <ul style="list-style-type: none"> • Esophageal transit, • Gastro- esophageal reflux, • Gastric emptying and motility • Describe the pathophysiology of intestinal disorders • Elaborate on radiopharmaceuticals Imaging protocol/s, processing and scan interpretation for <ul style="list-style-type: none"> ➤ Meckel’s diverticulum, ➤ Gastrointestinal bleed • Describe the pathophysiology of liver and spleen disorders • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for liver and spleen <ul style="list-style-type: none"> ➤ Structural ➤ functional imaging 	17
Unit 4		
Respiratory System	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe the pathophysiology obstructive pulmonary disease • Describe the pathophysiology of Pulmonary embolism and Ventilation perfusion mismatch • Describe the pathophysiology of right to left cardiac shunt • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis <ul style="list-style-type: none"> ➤ lung ventilation ➤ lung perfusion imaging, ➤ right to left cardiac shunt imaging 	12
Main Reference:	<ol style="list-style-type: none"> 1. Robbins & Cotran Pathologic Basis of Disease, 9e, Elsevier – 2013 2. Nuclear Medicine – The Requisites Harvey A. Ziessman Janis P. O’Malley James H. Thrall 	
Additional References	<ol style="list-style-type: none"> 1. Nuclear medicine technology and techniques Donald Bernier 2. Mosby’s Manual of Nuclear Medicine procedures D. Bruce Sodee 	

BNM3505 – PRACTICUM - V

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1 : Radiopharmaceuticals in Nuclear Medicine		
Radiopharmaceuticals in Nuclear Medicine practical	<ul style="list-style-type: none"> ● To perform elution & interpret elution efficiency of PET Radiotracers from Radionuclide generator ● To demonstrate & interpret quality checks of PET Radiopharmaceuticals ● To demonstrate process for ordering of Radiopharmaceuticals and cold kits ● To demonstrate record keeping of daily elution in Radio pharmacy laboratory ● To demonstrate record keeping of Inventory & stock of cold kits Radioactive materials ● Handling of Radioactive Spillage and contamination ● To demonstrate radiopharmaceutical biodistribution 	25
Unit 2 : Clinical Nuclear Medicine – I		
Clinical Nuclear Medicine - I	<ul style="list-style-type: none"> • To perform PET Fusion Imaging (18 F- FDG Scan) in Hematological malignancies • To perform PET Fusion Imaging (18 F- FDG Scan) for Prostate Cancer/Bladder Cancer/Renal cell carcinoma • To perform PET Fusion Imaging (18 F- FDG Scan) for Thyroid Cancer • To perform PET Fusion Imaging (18 F- FDG Scan) for Neuro endocrine Pancreatic Cancer – metabolic characterization (• To perform PET Fusion Imaging (18 F- FDG Scan) for Hepatocellular Carcinoma/ Spleen Cancer / Liver Cancer • To perform PET Fusion Imaging (18 F- FDG Scan) of Brain F-18 scan Alzheimer’s disease/ Epilepsy/ Dementia • To perform PET Fusion Imaging (18 F- FDG Scan) for cardiac PET Scan • To perform PET Fusion Imaging (18 F- FDG Scan) for Sarcoidosis -Cardiac sarcoidosis and pulmonary sarcoidosis • To perform PET Fusion Imaging (18 F- FDG Scan) for lung cancer diseases • To Perform PET Fusion Imaging (18 F- FDG scan) for treatment planning & assessment of early therapy response • To perform PET Fusion Imaging (18 F- FDG Scan) for fever of Unknown origin • To perform PET Fusion Imaging (18 F- FDG Scan) for oncological malignant imaging • To perform PET Fusion Imaging (18 F- FDG Scan) for benign Non-oncological imaging • To perform PET Fusion Imaging (18 F- FDG Scan) for Breast Cancer 	40
Unit 3 : Therapeutic Nuclear Medicine		

Therapeutic Nuclear Medicine	<ul style="list-style-type: none"> ● To demonstrate dispensing and oral administration of I-131 ● To demonstrate dispensing and intravenous administration of I-131 MIBG/Sm-153 	10
Main Reference	<ol style="list-style-type: none"> 1. Nuclear Medicine Technology & Techniques: Donald Bernier et.al 2. Physics in Nuclear Medicine: Sorenson 3. Physics in Nuclear Medicine: Sorenson 	
Additional References	<ol style="list-style-type: none"> 1. Mosby's Manual of Nuclear Medicine Procedures: D.Brucee Sodee, Paul J early 2. Quality control of Nuclear Medicine instruments: Tecdoc 602 3. Nuclear Medicine – The Requisites: Ziessman et. Al 4. Mosby's Manual of Nuclear Medicine Procedures: D.Brucee Sodee, Paul J early 5. Quality control of Nuclear Medicine instruments: Tecdoc 602 6. Nuclear Medicine – The Requisites: Ziessman et. al 	

BNM3506 – CLINICAL PRACTICE - IV

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Radiopharmacy Practices	<ul style="list-style-type: none"> • To arrange Radiopharmacy lab for daily activities • To identify and produce the inventory • To perform QC of dose calibrator • To prepare and dispense radiopharmaceuticals • To perform QC of radiopharmaceutical • To express procedures to patient and to practice as per regulatory guidelines • To write and maintain registers 	34
Unit 2		
In-vitro Nuclear Medicine Practices	<ul style="list-style-type: none"> • To locate and identify stock inventory • To maintain various non-imaging and radiation monitoring equipment • To perform radiation surveillance and produce the reports • To write and maintain registers 	21
Unit 3		
Scintigraphy Practices	<ul style="list-style-type: none"> • To arrange imaging room for daily activities • To perform daily QC of imaging and other accessory devices • To express procedures to patient and to practice as per regulatory guidelines • To write and maintain registers 	28
Unit 4		
Radionuclide Therapy Practices	<ul style="list-style-type: none"> • To locate and identify stock inventory • To practice QC of dose calibrator • To observe preparation and dispensing of therapeutic radiopharmaceuticals • To practice QC of radiopharmaceuticals • To express procedures to patient and to practice as per regulatory guidelines • To maintain radiation exposure records • To write and maintain registers 	22
Main Reference	<ol style="list-style-type: none"> 1. Radiopharmaceuticals in Nuclear Medicine Pharmacy and Nuclear Medicine - Kowalsky, Richard J., and Steven W. Falen 2. Nuclear Medicine-The Requisites : Harvey A. Ziessman, Janis P. O'Malley, James H. Thrall 	
Additional References	<ol style="list-style-type: none"> 1. Radiopharmaceuticals and Hospital Radiopharmacy Practices - N. Ramamoorthy BRIT 2. Radiation safety in Nuclear Medicine - AERB Mumbai 3. Nuclear Medicine Technology: Procedures and Quick Reference - Pete Shackett 	

BNM3601 – TOMOGRAPHY AND HYBRID IMAGING

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Mathematics in Instrumentation	<ul style="list-style-type: none"> • Explain the use of mathematics in Instrumentation in Nuclear Medicine • Apply Vectors in instrumentation in Nuclear Medicine • Apply Matrices in instrumentation in Nuclear Medicine • Apply Determinants in instrumentation in Nuclear Medicine • Explain the Interpolation and apply its use in instrumentations • Transformation and apply its use in instrumentations • Explain uptake Calculation • What is Calibration factors and calculations 	10
Mathematics in image reconstruction	<ul style="list-style-type: none"> • What is Fourier Transformation • Explain Fourier Transformation use in Image Reconstruction. • What is Laplace Transformation Z transformation • Explain and apply the Interpolation in image reconstruction • Explain Attenuation correction using radon transformation in Nuclear Medicine • Explain and Solve Iterative reconstructions 	10
Counting Errors:	<ul style="list-style-type: none"> • Explain types of errors • Explain the measuring errors • Explain Type I error and Type II error 	5
Propagational errors:	<ul style="list-style-type: none"> • Define and demonstrate propagation errors and used as sums and differences • Explain propagation error used as products and ratios and demonstrate complicated combination • Application of propagation error in effects of average, counting rates • Demonstrate the errors in effects of background, MDA and compare counting system in Nuclear Medicine • Analyse the optimization of Time, Counting error in Image • Uncertainty calculation in all the nuclear medicine experiments • Apply statistical tests in counting statistics 	10
Unit 2		

<p>Computed Tomography and Magnetic Resonance Imaging</p>	<ul style="list-style-type: none"> • Introduction to computed tomography • Generations of X-ray CT • Design and working principle of CT • Components of CT , Reconstruction techniques , Performance characteristics and quality control aspects • Introduction to MRI • Design and working principle of MRI • Components of MRI , • Reconstruction techniques , • Performance characteristics and quality control aspects 	<p>10</p>
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CONTENT	COMPETENCIES	NO. OF HOURS
Unit 3		
Hybrid Imaging Devices	<ul style="list-style-type: none"> • Principle of modality co-registration SPECT- CT, PET-CT, PET-MR • Co-registration of images 	15
Main Reference:	1. Physics in Nuclear Medicine by Sorenson 2. Text Book of Mathematics by Grawel B.S.	
Additional References	<ol style="list-style-type: none"> 1. Nuclear Medicine by Robert E. Henkin, Mark A. Boles 2. Mosby's Manual of Nuclear Medicine Procedures by D.Brucee Sodee, Paul J Early 3. Medical Imaging Physics by William R.Hendee, Russell Ritenour 4. Nuclear Medicine Physics by Ramesh Chandra 	

BNM3602 – INTRODUCTION TO AI AND RECENT ADVANCES IN NUCLEAR MEDICINE

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Introduction to Artificial Intelligence		
	<ul style="list-style-type: none">• To illustrate history and evolution of AI in medicine• To understand the core concepts of AI, Machine learning and deep learning• To understand different types of machine learning: supervised, unsupervised, reinforcement learning• To provide overview of neural networks and CNN	4
Unit 2: AI in Medical Imaging		
	<ul style="list-style-type: none">• To understand role of AI in Image pre-processing and noise reduction (AI filters in PET/SPECT)• To understand role of AI in image reconstruction using AI (deep learning–based PET/SPECT reconstruction)• To understand role of AI in Lesion detection and segmentation using CNNs• To understand role of AI in Quantification improvements with AI	14
Unit 3: AI in Nuclear Medicine Workflow		
	<ul style="list-style-type: none">• To understand the role of AI in patient scheduling, workflow optimization, and radiation safety• To understand the role of AI in dosimetry and treatment planning in radionuclide therapy• To understand the role of AI in predictive analytics in theranostics (e.g., Lu-177, I-131 therapies)• To understand the role of AI in Automation in quality control of imaging equipment	14
Unit 4: AI in Radiopharmacy and Research		
	<ul style="list-style-type: none">• To understand the role of AI in radiopharmaceutical discovery and development• To understand the role of AI in predictive modelling for tracer kinetics• To understand the role of AI in data mining in clinical trials and big data in nuclear medicine• To understand the role of AI in applications in personalized medicine and drug response prediction	14
Unit 5: Ethical, Legal, and Professional Aspects		
	<ul style="list-style-type: none">• To understand the role of AI in data privacy, patient consent, and GDPR/HIPAA perspectives• To understand the role of AI in bias in AI algorithms and its clinical impact• To understand the role of AI in regulatory approvals (FDA, CE) for AI software in nuclear medicine	14

Main Reference:	<ul style="list-style-type: none"> • Artificial Intelligence in Medical Imaging – Lei Xing & James Orton. • Nuclear Medicine Physics – International Atomic Energy Agency (IAEA) modules (with AI add-ons). • Digital Image Processing – Gonzalez and Woods • Artificial Intelligence in Medical Imaging – Erik R. Ranschaert, Sergey Morozov, Paul R. Algra, Springer; covers AI applications in nuclear medicine. • Deep Learning for Medical Image Analysis – S. Kevin Zhou, Hayit Greenspan, Dinggang Shen, Academic Press; provides deep learning techniques for imaging. 	
Additional References	<ul style="list-style-type: none"> • Machine Learning in Medicine – Ton J. Cleophas, Aeilko H. Zwinderman, Springer; supports machine learning applications. • Radiomics and Radiogenomics – Ruijiang Li, Lei Xing, Sandy Napel, CRC Press; covers radiomics for nuclear medicine. • Artificial Intelligence in Healthcare – Adam Bohr, Kaveh Memarzadeh, Springer; addresses ethics and validation. 	

BNM3603 – CLINICAL NUCLEAR MEDICINE - II

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Cardiovascular System	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe pathophysiology of cardiovascular disorders • Elaborate on Myocardial perfusion scintigraphy <ul style="list-style-type: none"> ➤ Interpretation • Elaborate on multi-gated acquisition, radionuclide ventriculography <ul style="list-style-type: none"> ➤ Radiopharmaceuticals ➤ Procedure for calculation of ejection fraction and first pass extraction ➤ Image processing ➤ Interpretation and quantitative analysis 	15
Unit 2		
Genitourinary System:	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe the pathophysiology of hydronephrosis, tubular obstruction, renovascular hypertension, vesico-uretral reflux • Elaborate on renal dynamic imaging Renogram, diuretic renogram, Captopril renogram study <ul style="list-style-type: none"> ➤ Radiopharmaceutical ➤ Procedure ➤ Time activity curve characteristics ➤ Image processing ➤ Interpretation and quantitative analysis • Elaborate on renal cortical imaging study <ul style="list-style-type: none"> ➤ Radiopharmaceuticals ➤ Procedure ➤ Interpretation • Describe vesicoureteral reflux (VUR) study <ul style="list-style-type: none"> ➤ Radiopharmaceuticals ➤ Protocol for direct and indirect VUR scan ➤ Image processing ➤ Interpretation and quantitative analysis 	15

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 3		
Central Nervous System	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the system • Describe pathophysiology of dementia, epilepsy brain death, hydrocephalus • Elaborate on brain perfusion imaging describing radiopharmaceuticals Imaging protocol/s, processing, scan interpretation for <ul style="list-style-type: none"> ➤ Various forms of dementia ➤ Epilepsy ➤ Brain death ➤ Blood brain barrier integrity ➤ Brain tumors ➤ Brain metabolism • Elaborate on radionuclide cysternography describing radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for <ul style="list-style-type: none"> ➤ Hydrocephalus ➤ Cerebrospinal fluid (CSF) leak ➤ CSF shunt patency 	15
Unit 4		
Miscellaneous Studies	<ul style="list-style-type: none"> • Recall important anatomical and physiological features of the immune system, basic immuno biology, lymphatic system • Describe the pathophysiology of infection and inflammation in general • Elaborate on radiopharmaceuticals Imaging protocol/s, processing, scan interpretation and quantitative analysis for <ul style="list-style-type: none"> ➤ Non skeletal infection imaging ➤ Lympho-scintigraphy ➤ Dacroscintigraphy ➤ Sialoscintigraphy ➤ Testicular Scintigraphy ➤ Immunoscintigraphy 	7
Unit 5: Radionuclide therapy		
General principles of Radionuclide therapy	<ul style="list-style-type: none"> • What are the physical and chemical characteristics of therapeutic radionuclides? • Relate interaction of therapeutic radionuclide with matter/ body/ disease • Recall radiation safety in radionuclide therapy • Explain routes of radionuclide therapy • Extend the effects of radionuclide therapy 	8
Main Reference:	<ol style="list-style-type: none"> 1. Robbins & Cotran Pathologic Basis of Disease, 9e, Elsevier – 2013 2. Nuclear Medicine – The Requisites Harvey A. Ziessman Janis P. O’Malley James H. Thrall 	

Additional References	1. Nuclear medicine technology and techniques Donald Bernier 2. Mosby's Manual of Nuclear Medicine procedures D. Bruce Sodee	
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BNM3604 – PRACTICUM - VI

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1: Tomography and hybrid imaging		
Tomography and hybrid imaging	<ul style="list-style-type: none"> • To perform pixel size test • To perform SPECT QC • To perform Daily tube, warm up of SPEC/CT and PET/CT, air calibration. • To perform PET Daily QC 	12
Unit 2 : Clinical Nuclear Medicine –II		
Clinical Nuclear Medicine –II	<ul style="list-style-type: none"> • To perform Radionuclide ventriculography • To perform Myocardial perfusion imaging • To perform Myocardial viability imaging • To perform Cortical imaging • To perform Renal dynamic scan/ Transplant evaluation • To perform DRCG/VCUG • To perform Radionuclide cisternography • To perform Ventriculo-peritoneal shunt evaluation • To perform Brain perfusion imaging • To perform Infection imaging • To perform Lymphoscintigraphy • To perform Dacrosintigraphy • To perform Sentinal lymphnode imaging • To perform Sialoscintigraphy 	58
Unit 3 : Counting statistics		
Counting statistics	<ul style="list-style-type: none"> • Explain, apply and analyse the effect of background in NM • Explain, apply and analyse the Counting Rate uncertainty in NM • Explain, apply and analyse the Comparison of various Counting systems • Explain, apply and analyse the Minimum detectable activity of the counting instruments • Demonstrate the pipetting Efficiency using weighing balance • Explain, apply and analyse the pipetting Efficiency using radioactivity 	20
Main Reference	<ol style="list-style-type: none"> 1. Nuclear Medicine Technology & Techniques Donald Bernier et.al 2. Physics in Nuclear Medicine Sorenson 3. Mosby’s Manual of Nuclear Medicine Procedures D.Bruce Sodee, Paul J 	
Additional References	<ol style="list-style-type: none"> 1. Quality control of Nuclear Medicine instruments Tecdoc 602 2. Nuclear Medicine - The Requisites-Harvey A. Ziessman Janis P. O’Malley, James H. Thrall 	

BNM3605 – CLINICAL PRACTICE - V

CONTENT	COMPETENCIES	NO. OF HOURS
Unit 1		
Radiopharmacy Practices	<ul style="list-style-type: none"> • To execute the arrangement of Radiopharmacy lab for daily activities • To execute identification and production of the inventory • To execute QC of dose calibrator • To prepare, dispense and administer radiopharmaceuticals • To execute QC of radiopharmaceutical • To perform nuclear medicine clinical procedures as per regulatory guidelines • To write and maintain registers 	45
Unit 2		
In-vitro Nuclear Medicine Practices	<ul style="list-style-type: none"> • To execute operation of various non-imaging and radiation monitoring equipment • To produce, analyze and comment on QA reports of all devices in Nuclear Medicine • To analyze and execute radiation surveillance reports • To write and maintain registers 	30
Unit 3		
Scintigraphy Practices	<ul style="list-style-type: none"> • To execute arrangement of imaging room for daily activities • To execute daily QC of imaging and other accessory devices • To perform and analyze procedures to patient and to practice as per regulatory guidelines • To perform scans and processing techniques • To write and maintain registers 	45
Unit 4		
Radionuclide Therapy Practices	<ul style="list-style-type: none"> • To execute QC of dose calibrator, fumehood • To prepare, dispense and administer radiopharmaceuticals • To execute QC of radiopharmaceutical • To express procedures to patient and to practice as per regulatory guidelines • To maintain radiation exposure records 	30

