M.S. Medical Physics Programme

REVISION 2022

Department of Physics & Applied Mathematics
Pakistan Institute of Engineering & Applied Sciences
Nilore, Islamabad 45650, Pakistan

M. S. (Medical Physics)

Semester-wise Layout of Courses

(**Revision 2022**)

NOTE: *'C' and 'O' stand for 'Compulsory' and 'Optional', respectively.*

SPRING SEMESTER				
1	PAM501	Applied Mathematics *(only for candidates who have not attended zero semester)*	3	C
2	PAM535	Anatomy, Physiology & Medical Terminology	3	C
3	PAM526	Introduction to Nuclear Physics*	3	O
4	NE502	Radiation Interaction & Detection	3	C
5	PAM532	*Radiation Biology***	3	C
SUMMER SESSION				
6	PAM539	*Physics of Radiotherapy***	3	C
7	PAM540	Radiation Safety Principles and Techniques	3	C
8	CMS501	Communication Skills	1	C
FALL SEMESTER				
9	PAM548	*Physics of Radiology***	3	C
10	PAM542	Radiation Detection and Clinical Laboratory	3	C
11	PAM513	Computing in Medical Physics *(compulsory for fellowship programme)*	3	O
12	PAM639	Recent Trends in Radiotherapy *(compulsory for fellowship programme)*	3	O
13	PAM538	*Physics of Nuclear Medicine***	3	C
14	PAM552	Laser Tissue Interaction	3	O
15	PAM629	Special Topics in Medical Physics-I	3	O
SPRING SEMESTER & SUMMER SEMESTER				
16	PAM697	Thesis projects	6	C
17	PAM695	Health Physics Attachment	3	C
18	PAM696	Clinical Attachment	3	C

*The course PAM 526 is optional but may be treated as compulsory for students having background other than physics.

**Core Courses of MS Medical Physics programme. Mandatory for award of the degree

MS (MP) Course (Minimum Requirement: 25 CH of course work, 6 CH of thesis project and 6 CH of Trainings). A minimum of 37 credit hours are required for the award of degree. For PAEC/other fellowships additional courses as mentioned above must be taken as well.

Details of the Courses

Spring Semester

PAM501 APPLIED MATHEMATICS

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Partial derivatives of explicit and implicit functions; Maxima and minima of function of several variables; Multiple integrals and their applications; Bessel functions; Legendre functions; Gamma functions; error function; Series solution of differential equations; Fourier transforms; Types and methods of solution of Partial differential equations; Vector and Tensor Calculus; Coordinate Transformation system including Curvilinear coordinates

Recommended Texts:

- Kreyszig, E. "Advanced Engineering Mathematics", 9th edition, John Wiley and Sons, 2005.
- Berret, C.R. "Advance Engineering Mathematics," 5th edition, John Wiley & Sons, USA, 1994.
- Munem, M.A. and Foulis, D.J. "Calculus and Analytical Geometry," Worth Publishing Co., USA, 1995.
- Dalrymple. G.V. "Mathematical Principles In Basic Science of Nuclear Medicine", The CV Mosby Company, 1974.
- Martin, P.M. "Nuclear Medicine Statistics, In Nuclear Medicine Physics, Instrumentation & Agents", The CV Mosby Company, 1977.

PAM535 ANATOMY PHYSIOLOGY & MEDICAL TERMINOLOGY

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Four hours of lectures per week

Organization of the Human Body; Cells and Tissues; The Integumentary System; The Skeletal System; The Muscular System; The Endocrine System; The Nervous System; Somatic Senses and Special Senses; The Cardiovascular System: Blood, Heart, Blood Vessels, and Circulation; The Lymphatic System and Immunity; The Respiratory System; The Digestive System: Nutrition and Metabolism; The Urinary System, Fluid, Electrolyte, and Acid–Base Balance; The Reproductive Systems

Recommended Texts:

- Scanlon, Valerie C., and Tina Sanders. Essentials of anatomy and physiology. FA Davis, 2018.
- Freudenrich CC, Tortora GJ. Visualizing Anatomy & Physiology. John Wiley & Sons, Inc. Denver, USA, 2011.
- Jenkins G, Tortora GJ. Anatomy and Physiology: From Science to Life 3rd edition. John Wiley & Sons, Inc. Denver, USA, 2012.

PAM526 INTRODUCTION TO NUCLEAR PHYSICS

Optional	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Atomic & nuclear structure, artificial & natural radioactivity, Modes of radioactive decay, exponential decay, Half-life & mean life of radionuclides, radioactive decay series & equilibrium, Nuclear Reaction & reaction cross-section, nuclear fission & fusion, Nuclear fuel cycle & nuclear reactors, Cyclotron & particle accelerators; Poison and Gaussian distribution; Applications of statistical analysis; Chi-square test; Elementary concepts of probability; Test of significance; Statistical criteria for the selection and adjustment of counters, T-tests, P-values, variances, confidence intervals, statistical results and their interpretations, medical statistics.

Recommended Texts:

- Martin, A. and Harbison, S.A." An Introduction to Radiation Protection," (3rd ed.), Chapman and Hill, 1986.
- Sorenson, J.A. and Phelps, M.E. "Physics in Nuclear Medicine",Grune and Stratton, 1980.
- Rahman, I. and Shieh, P.S. "Introduction to Nuclear Engineering", Robert E. Krieger Publishing Company, Inc., 1981.
- Parker, R.P., Smith, P.H.S. and Taylor, D.M. "Basic Science of Nuclear Medicine",Churchil Livingstone, 1984.
- Kaplan, I. "Nuclear Physics", Addison - Wesley Publishing Company, 1972.

NE502 RADIATION INTERACTION & DETECTION

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Radiation sources; Interaction of radiation with matter, Basic principles of radiation detection; Design aspects of ionization chambers, Proportional and Geiger-Muller counters: Various types of scintillators; Scintillation detectors; Radiation spectroscopy using Scintillation detectors: Semiconductors; Various types of semiconductor detectors and their characteristics. Neutron sources; Neutron detection techniques and neutron spectroscopy. Basic electronic circuits and electronic equipment used in nuclear radiation detection systems; Measure of central tendency and dispersion; Concepts of sample space, events, random variables and probability; Probability distributions (discrete & continuous); Curve fitting and tests for goodness of fit; Errors and their propagation; Counting statistics.

Recommended Texts:

- Knoll G. F. Radiation Detection & Measurements, 3rd Ed., John Wiley, 2005.
- Lamarsh,J. R. Introduction to Nuclear Engineering, 3rd Edition, Addison-Wesley, 2001.
- Martin, A. and Harbison, An Introduction to Radiation Protection, 3rd Ed., Chapman & Hill, 1986.
- Sorenson, J.A. and Phelps, M.E. "Nuclear Counting Statistics In Physics and Nuclear Medicine",Grune& Stratton, 1980.

PAM532 RADIATION BIOLOGY

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Physics and Chemistry of Radiation Absorption, DNA Strand Breaks and Chromosomal Aberrations, Cell Survival Curves, Radiosensitivity and Cell Age in the Mitotic Cycle, Repair of Radiation Damage and the Dose-Rate Effect, Oxygen Effect and Reoxygenation, Linear Energy Transfer and Relative Biologic Effectiveness, Acute Effects of Total-Body Irradiation, Radioprotectors, Radiation Carcinogenesis, Hereditary Effects of Radiation, Effects of Radiation on the Embryo and Foetus, Radiation Cataractogenesis, Dose-Response Relationships for Model Normal Tissues, Clinical Response of Normal Tissues, Model Tumor Systems, Time, Dose, and Fractionation in Radiotherapy, Alternative Radiation Modalities, Radiosensitizers, Hyperthermia

Recommended Texts:

1. Hall, E. J., Giaccia, A. J., Radiobiology for the Radiologist, Walter Kluwers; 8th edition., 2019.
2. Joiner, Michael C., and Albert J. van der Kogel, eds. Basic Clinical Radiobiology. 5th edition CRC press, 2018.
3. Sureka, C. S., and Christina Armpilia. Radiation Biology for Medical Physicists. CRC Press, 2017.
4. Training course series 42, "Radiation Biology: A handbook for teachers and students", IAEA-2010.

Summer Session

PAM539 PHYSICS OF RADIOTHERAPY

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Four hours of lectures per week

Dosimetric Principles, Treatment Machines for External Beam Radiotherapy and Their Calibration, External Photon Beam Physical Aspects, Depth of dose maximum, Percent Depth Dose, Tissue-Air Ratio, Relationship between TAR and PDD, Clinical Treatment Planning in External Photon Beam Radiotherapy, Electron Beams Physical and Clinical Aspects, Profiles and off-axis ratio, flatness and symmetry, clinical considerations, Acceptance Tests and Commissioning Measurements, acceptance test, safety checks, central axis percentage depth dose, multi-leaf collimators, Computerized Treatment Planning Systems for external photon beam therapy, calculation algorithms, optimization and monitor unit calculations, quality assurance, Quality Assurance of External Beam Radiotherapy, Brachytherapy; Physical and clinical aspects, dose calculation procedures, calibration chain.

Recommended Texts:

1. John P. Gibbons. Khan's the physics of radiation therapy, 6th edition. Lippincott Williams & Wilkins, 2019.
2. Todd Pawlicki, Daniel J. Scanderbeg, George Starkschall. Hendee's Radiation Therapy Physics, 4th edition. John Wiley & Sons, 2016.
3. Khan, Faiz M., John P. Gibbons, and Paul W. Sperduto. Khan's treatment planning in radiation oncology, 5th edition. Lippincott Williams & Wilkins, 2021.
4. Podgorsak, Ervin B. "Radiation oncology physics." a handbook for teachers and students" International Atomic Energy Agency, 2005.
5. David Greene, D. Greene, & P. C. Williams, Linear Accelerators for Radiation Therapy, Institute of Physics Publishing, 1998.

PAM540 RADIATION SAFETY PRINCIPLES AND TECHNIQUES

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Introduction, Radiation quantities & units, International organizations setting standards, Latest IAEA Basic Safety standards, Fundamental Safety Principles, Safety standards for medical exposure, Principles & control of external & internal exposure hazards, absorbed dose estimation from external exposure, Health Physics instrumentation, Dose estimation from internally deposited radionuclides, Radiation safety in Radionuclide therapy for patients, family members & the general public, IAEA Safety regulations for transport of radioactive materials, Radiation accident management & early medical treatment of radiation injury, Patient doses audit, Shielding and other design considerations for medical facilities, Regulatory and licencing requirements for medical facilities, Radioactive waste disposal methods, Handling of I-131 therapy patients. Practical demonstrations of radiation protection procedures in health physics, i.e., SSDL, whole body counting, bioassay counting, Verification of inverse square law, Calibration of survey meters, Bioassay technique, TLDs, Contamination and decontamination, Film badge dosimetry.

Recommended Texts:

- Thomas E. Johnson., Introduction to Health Physics, McGraw-Hill Education / Medical; 5th edition, 2017.
- IAEA Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - Interim Ed. General Safety Requirements Part 3, No. GSR Part 3, 2014.
- IAEA Fundamental Safety Principles, Series No. SF-1, published Tuesday, November 07, 2006.
- INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, Specific Safety Requirements, 2018
- IAEA SRS-63, Release of patients after Radionuclide therapy, 2009
- Martin, A., Harbison, S., Beach, K., & Cole, P., An introduction to radiation protection. CRC Press, 2018.
- ICRP Publication No. 26:"Recommendations of International Commission on Radiological Protection", Pergamon Press, 1977.
- Jeager, R.J., et al. "Engineering Compendium on Radiation Shielding", Springer - Verlag, 1968.

Fall Semester

PAM548 PHYSICS OF RADIOLOGY

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Image quality, Digital Filtering, Signal to Noise Ration, Contrast to Noise Ratio, Modulation Transfer Function, Noise Power Spectrum, ROC Curves, Mammography, Digital Tomosynthesis, Digital subtraction angiography (DSA); Computed Tomography, Image reconstruction, patient dosimetry; Ultrasound, reflection, transmission, transducers; MRI, relaxation times, k-space, contrast agents, pulse sequence; Quality assurance.

Recommended Texts:

- Samei, Ehsan, and Donald J. Peck. Hendee's physics of medical imaging. John Wiley & Sons, 2019.
- Bushberg, Jerrold T, Seibert J. Anthony, Leidholdt, Jr , Edwin M., Boone John M. ., The Essential Physics of Medical Imaging, 4th Edition, Lippincott Williams & Wilkins , 2020.
- Flower, Maggie A., ed. Webb's physics of medical imaging. CRC Press, 2012.
- Bushong, Stewart C. Radiologic Science for Technologists E-Book: Physics, Biology, and Protection. Elsevier Health Sciences, 2020.

PAM513 COMPUTING IN MEDICAL PHYSICS

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Computing Fundamentals, Memory Management systems, Digital Image processing techniques using Matlab; smoothing, interpolation, edge enhancement, etc., Digital Imaging and Communications in Medicine (DICOM), Picture Archiving and Communication Systems (PACS) Image reconstruction techniques in CT, Nuclear medicine and MRI, Fast Fourier transforms and its application to imaging; Fundamentals of Monte Carlo simulations,GEANT4 Monte Carlo simulation toolkit of radiation. EGSnrc Monte Carlo Simulation code.

Recommended Texts:

- Joos, Irene, Ramona Nelson, and Marjorie J. Smith. Introduction to computers for healthcare professionals. Jones & Bartlett Publishers, 2010.
- Gonzalez, Rafael C., Richard E. Woods, and Steven L. Eddins. Digital image processing using MATLAB. Vol. 2. Knoxville: Gatesmark Publishing, 2009.
- Huang, H. K. PACS and imaging informatics: basic principles and applications. Wiley, 2010.
- Pianykh, Oleg S. Digital imaging and communications in medicine (DICOM): a practical introduction and survival guide. Springer, 2012.
- Kalos, Malvin H., and Paula A. Whitlock. Monte Carlo methods. John Wiley & Sons, 2008.
- Dupree, Stephen A., and Stanley K. Fraley. A Monte Carlo primer: A Practical approach to radiation transport. Vol. 1. Springer, 2002.

PAM538 PHYSICS OF NUCLEAR MEDICINE

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Introduction to nuclear medicine, Radiopharmaceuticals, Basic principles & licensing considerations, Production of radioisotopes, Radioisotope generators, Dosage control techniques, Quality Control (QC) & Quality Assurance (QA) of radiopharmaceuticals, collimators, types and applications, quality control considerations in collimators, gamma camera and its components, Quality Control and Quality Assurance procedures of gamma camera, maintenance considerations, Computers in nuclear medicine: Creation of digital image, Data Analysis, Data display and formatting, Principles of SPECT and SPECT-CT, QC and QA procedures for SPECT, Introduction to non-imaging probes & solid state gamma cameras. Physics of Positron Emission Tomography (PET) and PET-CT, coincidence circuitry, PET-CT camera, Quality assurance and quality control for PET-CT

Recommended Texts:

1. Cherry, Simon R., James A. Sorenson, and Michael E. Phelps. Physics in nuclear Medicine, 4th Edition, Elsevier Health Sciences, USA, 2012.
2. Bailey, D. L., and J. L. Humm. Nuclear Medicine Physics: A Handbook for Teachers and Students. IAEA, 2014.
3. Chandra, Ramesh, Nuclear Medicine Physics: The Basics, 6th Edition, Lippincott Williams & Wilkins, 530 Walnut Street, Philadelphia, PA 19106, USA, 2004.
4. Bushberg, Jerrold T, Seibert J. Anthony, Leidholdt, Jr , Edwin M., Boone John M. ., The Essential Physics of Medical Imaging, 4th Edition, Lippincott Williams & Wilkins , 2020.
5. Rachel A. Powsner, Matthew R. Palmer, Edward R. Powsner, "Essentials of Nuclear Medicine Physics and Instrumentation, 3rd Edition, Wiley-BlackWell, New York, USA, 2013.

PAM552 LASER TISSUE INTERACTION

Optional	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

Principles of lasers, properties of laser radiations, some laser systems. Light matter interaction, reflection, refraction, absorption, scattering, turbid media, measurement of optical properties. Interaction Mechanism: Thermal interaction, photo ablation, plasma-induced ablation, photo disruption, shock wave generation, cavitations, jet formation. New modalities of cancer treatment, photodynamic therapy, laser induced thermal therapy. Medical applications of lasers in: Ophthalmology, gynaecology, urology, etc. Laser safety: laser hazards, eye hazards, skin hazards, laser safety standards and hazard classification, eye protection.

Recommended Texts:

- Ikram M.and Hamza, M. Y. Optics and Lasers, AIOU, 1999.
- Tuchin, V.Tissue Optics, SPIE, Washington, 1999.
- Silfvast,W. T. Laser Fundamentals, Cambridge University Press, Cambridge, 2000.
- Niemz, M. Laser-Tissue Interaction, Springer-Verlag, Berlin, 2003.
- Hamblin, M. R., Mróz P, Mroz P, Advances in photodynamic therapy, Artech House, 2008.
- Gomers, C.J. Photodynamic Therapy: Methods and Protocols, Humana Press, 2010

PAM629 SPECIAL TOPICS IN MEDICAL PHYSICS-I

Optional	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

In this subject, the latest developments from time to time in the field of medical physics will be the main features. (Applications of lasers, ultraviolet and infrared light in medicine, diathermy, MRI)

PAM630 SPECIAL TOPICS IN MEDICAL PHYSICS-II

Optional	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

In this subject, the latest developments from time to time in the field of medical physics will be the main features.

PAM542 RADIATION DETECTION AND CLINICAL LABORATORY

Compulsory	
Credits	3
Pre-requisite	Nil
Course Format	Three hours of lectures per week

From the following list of experiments, a minimum of 5 experiments have to be performed by the students.

1. Characteristics of G.M tube, dead time measurement, beta attenuation and counting statistics.
2. Half-life measurement of different radioisotopes
3. Characteristics of a scintillation detector and determination of pulse height spectra of gamma source.

4. Determination of attenuation coefficients & build up factor for various shielding materials.
5. To study the effect of various parameters of x-ray machine on x-ray quality & quantity using x -ray simulator & x- ray machine
6. Gamma-Gamma coincidence experiment
7. Measurement of HVL of Lead & aluminium for various energies of X-ray machine
8. Preparation of various radiopharmaceuticals in the Hot Lab.
9. Flood field uniformity, resolution & other routine quality control tests of Gamma
10. Introduction to SPECT procedures on Gamma Camera, image reconstruction and quality control considerations for SPECT.
11. Thermoluminescence Dosimetry
12. 12. Reference Check Source Measurement

PAM639 RECENT TRENDS IN RADIOTHERAPY

Optional	
Credits	3
Pre-requisite	PAM 539
Course Format	Three hours of lectures per week

General description of a linear accelerator and its component systems; Basic processes in electron acceleration, The accelerating waveguide, Microwave system & its high-voltage supplies, Vacuum, cooling & ancillary systems, Electron beam (production & transport), Treatment head, Dose monitoring and control system, Mechanical systems, Control and interlock systems, Treatment verification, Radiation protection & room design, Accelerator operation, Simulators & topographic scanners, Contemporary developments, Installation & commissioning of Linear accelerators (linacs), testing procedures of linacs, mechanical testing & optical of linacs, beam shaping characteristics, Multileaf Collimators (MLCs), Portal imaging. Rationale of IMRT and its implementation, Image Guided Radiation Therapy and Particle beam therapy. Quality control in modern radiotherapy modalities.

Recommended Texts:

- Symonds, R. Paul, John A. Mills, and Angela Duxbury, eds. Walter and Miller's Textbook of Radiotherapy: Radiation Physics, Therapy and Oncology-E-Book. 2019.
- Advances in Medical Physics. Volume 6. Editors: Devon J. Godfrey, Shiva K. Das, and Anthony B. Wolbarst. Medical Physics Publishing; Madison, WI, 2016.
- John P. Gibbons. Khan's the physics of radiation therapy, 6th edition. Wolters Kluwer, 2019.
- Pawlicki, Todd, Daniel J. Scanderbeg, and George Starkschall. *Hendee's radiation therapy physics*. John Wiley & Sons, 2016.
- Khan, Faiz M., John P. Gibbons, and Paul W. Sperduto. Khan's treatment planning in radiation oncology, 5th edition. Lippincott Williams & Wilkins, 2021.
- David Greene, D. Greene, & P. C. Williams, Linear Accelerators for Radiation Therapy, Institute of Physics Publishing, 1998.
- Karzmark, C. J., Robert J., Morton, A. Primer on Theory and Operation of Linear Accelerators in Radiation Therapy, Medical Physics Publishing, 1997.

Spring Semester

PAM697 Thesis Project

Compulsory	
Credits	6
Pre-requisite	Nil
Course Format	Full time research for whole semester

One complete semester is reserved for M.S. Thesis Project. The student will undertake an in-depth study of a research problem. Each student shall complete the Thesis Project under the guidance of a Thesis Supervisor. A co-supervisor may also be assigned depending on the nature of the work involved. The work carried out by the student will be evaluated by the Project Supervisor (and Co-Supervisor, if any). Their evaluation will be aided by a panel of examiners, preferably from outside, appointed by the Head of the department in consultation with the Project Supervisor and Co-Supervisor. The student shall submit a comprehensive report and shall deliver at least one seminar before the completion of the Thesis Project and defend the thesis before the panel of examiners and the Thesis Supervisor, Co-Supervisor. At the end of the Thesis Project, the overall grade for research work performed will be given as Excellent, Very Good, Good, Satisfactory or Unsatisfactory.

Summer Semester

PAM695 Health Physics Attachment

Compulsory	
Credits	3
Duration	9-Weeks
Course Format	Full time clinical training for 9 weeks

Health Physics Attachment aims to provide the students with on job training in various applied aspects of Health Physics. It is carried out at Health Physics Division (HPD) and Isotope Production Division (IPD) in PINSTECH. Within HPD the students are trained in a number of subgroups such as, Environmental monitoring, Radiation Dosimetry, Secondary Standard Calibration Labs, Radiation Waste Management Group etc. Similarly at IPD the training involves, the isotope supply chain assessment including Technetium-99m generators and the production of Fission Moly. The entire 9 week activity is geared to equip Medical Physics graduates for fully undertaking a diverse set of health physics assignments ranging from personal to environmental dosimetry. At the end of Health Physics Attachment, the overall student assessment (Viva Voce/Presentation) is carried out. The grade for training work performed will be given as Excellent, Very Good, Good, Satisfactory or Unsatisfactory.

PAM696 Clinical Attachment

Compulsory	
Credits	3
Duration	9-Weeks
Course Format	Full time clinical training for 9 weeks

The purpose of clinical attachment is to provide practical training and hands-on experience with the techniques, methods and equipment that the graduates will be using in their profession career at the Cancer hospitals. During Clinical Attachment, each student is placed in a Medical Centre within in PAEC (includes all PAEC Medical Centres with radiation cancer treatment facility). The emphasis is laid on acquiring expertise in Radiotherapy, Radiology and Nuclear Medicine departments. External Beam Radiotherapy treatment planning and delivery, Brachytherapy are important features of Radiotherapy training. Mammography and CT along with x rays form the bulk of Radiology content. Gamma Camera from a Medical Physicist perspective and PET are the hall marks of Nuclear Medicine module. At the end of Clinical Attachment, the overall student assessment (Viva Voce/Presentation) is carried out. The grade for training work performed will be given as Excellent, Very Good, Good, Satisfactory or Unsatisfactory.