وصف المساقات ومخرجات التعلم والمراجع المقترحة لكل مساق

Course description, Suggested Readings and ILOs of the Program

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture		
3	--	3	Classical Physics	Undergraduate Classical Mechanics (APPH310)

Course Description:

This is an advanced course in classical Mechanics. Topics covered in this course include Hamilton's variational principle; Lagrangian mechanics; the central force problem; non-linear dynamics and phenomena of chaos; kinematics and dynamics of rigid bodies; small oscillations; the Hamiltonian formulation of mechanics; canonical transformations; the Poisson bracket formulation; Hamilton-Jacobi theory; action angle variables; continuous systems; and relativistic field theory.

Suggested Readings:

- H. Goldstein, Classical Mechanics 2nd Edition, Addision Wesley Publishing Co., 1980.
- E. J. Saletman and A.H. Cromer, Theoretical Mechanics, J. Wiley, 1971.
- A.L. Felter and J.D. Walecka, Theoretical Mechanics of Particle and Continua, McGraw-Hill,1980.
- T.W.B. Kibble, Classical Mechanics, McGraw Hill, 1966.
- L.D. Landau and E.M. Lifshitz, Mechanics 3rd Edition.
- J.B. Marion and S.T. Thornton, Classical Dynamics of Particles and Systems 3rd Edition.
- E.A. Desloge, Classical Mechanics I and II.
- TerHarr, Elements of Hamiltonian Mechanics 2nd Edition.
- H.C. Corben and P. Stehle, Classical Mechanics 2nd Edition.

Intended Learning Outcomes:

On successful completion of the course, students should be able to:

- explain the difference between Newtonian mechanics and Analytic mechanics
- solve the mechanics problems using Lagrangian formalism, a different method from Newtonian mechanics
- Discuss the connection between classical mechanics and quantum mechanics from Hamiltonian formalism
- Apply the Variational principle to real physical situations

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Classical Electrodynamics	Undergraduate Applied Electrodynamics (APPH422)
3	--	3		

Course Description:

Topics covered in this course include mathematical methods for electrostatic and magnetostatic source and boundary value problems. Electromagnetic fields from time-dependent source distributions. Interaction between electromagnetic fields and media. Special theory of relativity applied to electromagnetics.

Suggested Readings:

- J.D. Jackson, Classical Electrodynamics 2nd Edition, Wiley and Sons, New York, 1975.
- W.K.H. Panofsky and M. Phillips, Classical Electricity and Magnetism, Addison-Wesley, Reading, Mass, 1962.
- L.D. Landau and E.M. Lifshtiz, The Classical Theory of Fields 3rd Revised English Edition, Pergamon, Oxford and Addison-Wesley, Reading, Mass, 1971.
- P.M. Morse and H. Feshbach, Methods of Theoretical Physics, Vol. I and II, McGraw-Hill, New York, 1953.
- S. Wolfram, Mathematica, Addison-Wesley, Reading, Mass, 1988.

Intended Learning Outcomes:

After completion of the course the student shall be able to:

- explain Green's theorem; describe Green functions to Poisson's equation
- expand Green functions in orthogonal bases to solve electrostatic and magnetostatic boundary value problems
- do multiple expansions of electrostatic and magnetostatic fields
- elaborate on the physical implications of Maxwell’s equations
- describe Green functions to the wave equation
- calculate the retarded fields from continuous sources and point charges
- explain and use conservation laws for energy, momentum and angular momentum
- analyze propagation, reflection and transmission of plane waves
- describe the covariant form of Maxwell’s equations and apply the Lorentz transformation to 4-vectors and the field tensor

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Quantum Mechanics	Undergraduate Quantum Mechanics II (APPH432)
3	--	3		

Course Description:

This course gives a brief review of quantum mechanics including operators, linear vector spaces and Dirac notation; general theory of angular momentum and rotation group, addition of angular momentum, Clebsh-Gordan technique, scattering of spin ½ particles with spinless particles, tensor operators; time dependent perturbation theory. Other topics discussed include the interaction of radiation with matter, absorption of light, induced and spontaneous emission, electric and magnetic dipole transitions, selections rules and scattering of light.

Suggested Readings:

- E. Merzbacher, Quantum Mechanics 2nd Edition, J. Wiley and sons, 1970.
- H.A. Mavromatis, Exercises in Quantum Mechanics 2nd Edition, Kluwer Reidel, 1991.
- Fayyazuddin and Riazuddin, Quantum Mechanics, World Scientific, 1990.
- A. Messiah, Quantum Mechanics, Vols. I & II, 9th Edition, North-Holland, 1981.
- A.S. Davydov, Quantum Mechanics 2nd Edition, Pergamon Press, 1976.

Intended Learning Outcomes:

- To extend the students' ability to apply the formalism of quantum mechanics gained in their undergraduate degrees
- To introduce students to notation and concepts that will enable them to appreciate some of the recent results published on the interpretation and application of modern quantum mechanics.
- To familiarize students with advanced topics in non-relativistic quantum mechanics such as rotation group, interaction of radiation in the matter and quantization of the radiation field, using general formalism.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Mathematical Physics	Undergraduate Mathematical Physics (APPH322)
3	--	3		

Course Description:

This course provides students with the study of the application of mathematical techniques to the formulation and solution of physical problems, particularly those which occur in classical mechanics, thermodynamics, electromagnetic theory, and quantum mechanics. Topics include vector methods, generalized coordinates, functions of complex variable, computer algebra system and applications.

Suggested Reading:

- Introduction to Mathematical Physics. Michael T. Vaughn. ISBN-13: 978-3527406272
- Mathematical Methods for Physicists (fifth edition), by G.B. Arfken and H.J. Weber (Harcourt Academic Press, 2001)
- Complex Variables and Applications, by R.V. Churchill, J.W. Brown, and R.F. Verhey (McGraw-Hill, 1974)
- Mathematical Methods of Physics, by J. Matthews and R.L. Walker (Benjamin, 1970)

Intended Learning Outcomes:

After completed course, the student should:

- Have an understanding of the underlying mathematical methods in classical and modern physics.
- Be familiar with frequently encountered mathematical methods, equations, functions, and solutions occurring in advanced physics courses.
- Gain skill in the techniques of problem formulation and solution in mathematical physics.
- Be familiar with mathematical physics as a method for solving a great variety of problems in the physical sciences.
- Be able to illustrate the mathematical techniques with examples from theory and experiments in physics.
- Be able to provide an emphasis on practice in problem solving and to develop the experience and confidence to be able to apply the mathematical problem-solving techniques in a variety of applications.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Statistical Physics	Undergraduate Modern Physics (APPH250)
3	--	3		

Course Description:

This course introduces students to the statistical basis of thermodynamics; elements of ensemble theory, the canonical and grand canonical ensembles; quantum statistics, application to simple gases; Bose and Fermi systems; imperfect gas; phase transitions and Ising model.

Suggested Readings:

- Statistical Mechanics, by Pathria and Leale, Academic Press, Third Edition.
- Statistical Mechanics by R. Kubo, H. Ichimura, T. Usui, N. Hashitsume. ISBN-13: 978-0444871039
- Statistical Physics 3rd edition by by L D Landau , E.M. Lifshitz. ISBN-13: 978-0750633727

Intended Learning Outcomes:

After completing this course students should:

- have a working knowledge of the foundations, techniques and key results of statistical mechanics and thermodynamics
- be able to comprehend their basic applications at the research level, e.g., in research articles
- be able to read any other related statistical and thermal physics material as they need it.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Computational Physics	Undergraduate Computer Programming (GE114)
3	To be determined by instructor	3		

Course Description:

This course is comprised of both practical sessions and lectures. The instructor will decide on the number of practical exercises in the form of practical sessions and homework. The course introduces basic and advanced concepts in numerical techniques and shows their practical applications in some illustrative problems in physics. Topics include: a) elementary numerical procedures: differentiation, integration, determination of zeros; b) from the harmonic oscillator to chaotic systems; special attention will be paid to the variational method for the Schrodinger equation, the approaches to the many-electron problem: the Hartree-Fock theory and the density functional theory, solving the Schrodinger equation in periodic solids, review of the theory of classical statistical mechanics with emphasis on those issues which are relevant to computer simulations, and c) molecular dynamics simulations for studying classical many-particle systems.

Suggested Readings:

- J. M. Thijssen, Computational Physics(Cambridge University Press, Cambridge,1999)
- Joel Franklin, Computational Methods for Physics, Cambridge University Press (2013).
- Marvin L. De Jong, Introduction to Computational Physics, Addison-Wesley (1991).
- Paul L. DeVries and Javier E. Hasbun, A First Course in Computational Physics, 2nd ed., Jones and Bartlett (2010).
- Nicholas Giordano and Hisao Nakanishi, Computational Physics, second edition, Prentice Hall (2005).

Intended Learning Outcomes:

- Knowledge of advanced concepts and results of computational physics according to course contents;
- Ability to solve exercises in computational physics and to present the solutions to an audience.
- Students will be able to use topics within the field of physics as a context for learning and applying numerical techniques to solve them.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Nuclear Physics	Undergraduate Particle and Applied Nuclear Physics (APPH400)
3	--	3		

Course Description:

The course gives deepening knowledge about nuclear structure and hadron physics, the main areas of nuclear physics, including a certain level of training to carry out an experiment and the corresponding data analysis. Other topics covered in this course include nuclear properties., nucleon-nucleon interaction, scattering, nuclear models, strong and electromagnetic interaction, optical models, resonance scattering and nuclear reactions, including the calculation of the cross section for certain processes, production and decay of nucleon and meson resonances., quark structure of hadrons, symmetry properties of hadronic processes, and nuclear astrophysics.

Suggested Reading:

- M.A. Preston and R.K. Bhaduri, Structure of the Nucleus, Addison-Wesley.

Intended Learning Outcomes:

After passing the course the student should be able to :

- use symmetries, conservation laws and kinematical conditions in order to give physical explanations for nuclear physics processes
- account for different experimental methods that gives information on properties of hadrons and nuclei
- calculate nuclear physics quantities and processes
- describe how the structure of nuclei is related to the many-body system of interacting nucleons
- summarize the properties of exited nuclei and hadron resonances

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Elementary Particle Physics	Undergraduate Particle and Applied Nuclear Physics (APPH400)
3	--	3		

Course Description:

This course covers various topics including the standard model for electroweak and strong interactions, Feynman rules, quantitative comparing of theory and experiments for scattering and disintegration processes. It also investigates topics such as neutrino physics, (Cabibbo–Kobayashi–Maskawa) CKM mass mixing matrix, Higgs mechanism, supersymmetry and unified theories.

Suggested Readings:

- Beyond the Standard Model of Elementary Particle Physics. Yorikiyo Nagashima. ISBN: 978-3-527-41177-1.
- Elementary Particle Physics: Foundations of the Standard Model V2. Yorikiyo Nagashima. ISBN: 978-3-527-40966-2.
- Introduction to Elementary Particles , 2nd, Revised Edition. David Griffiths. ISBN: 978-3-527-40601-2.
- Quarks and Leptones: An Introductory Course in Modern Particle Physics. Francis Halzen, Alan D. Martin. ISBN: 978-0-471-88741-6.

Intended Learning Outcomes:

After completed course, the student should be able to:

- Calculate, using Feynman techniques, cross sections for various processes, as well as decay widths or lifetimes of particle resonances.
- Interpret experimental results within or beyond the Standard Model.
- Write project reports and prepare and hold short presentations.
- comprehend the Standard Model (SM) for Electroweak (EW) and Strong interactions (QCD)
- Comprehend quantitative comparison of theory and experiments for scattering and disintegration processes

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Atomic and Molecular Physics	Undergraduate Quantum Mechanics II (APPH432)
3	--	3		

Course Description:

This course focuses on atomic structure: single electron atoms, two electron atoms, multi-electron atoms (N-electron problems), atoms in external fields, interaction of atoms and light, electro-magnetic field quantization, transition rates, polarisation, oscillator strengths and their spectral distribution, molecular structure & spectra; diatomic molecular structure, spectra of diatomic molecules, long range interactions, scattering; basic concepts, potential scattering, applications, plus some extended topics.

Suggested Readings:

- Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics (Graduate Texts in Physics). 2nd ed. 2010. Wolfgang Demtröder. ISBN-13: 978-3642102974
- Physics of Atoms and Molecules (2nd Edition). B.H. Bransden , C.J. Joachain. ISBN-13: 978-0582356924

Intended Learning Outcomes:

On completion of the course, the student shall

- have advanced knowledge of modern atomic and molecular physics including quantum mechanical computational techniques
- master both experimental and theoretical working methods in atomic and molecular physics for making correct evaluations and judgments
- account for theoretical models, terminology and working methods used in atomic and molecular physics

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Solid State Physics	Undergraduate Solid State Physics (APPH471)
3	--	3		

Course Description:

In this course we cover various topics including crystal structure in real and reciprocal space, Bragg's law and diffraction techniques, defects in solids; vibrations in solids (phonons, mono and bi-atomic linear chain), heat capacity. We also explore topics on the free electron gas, Fermi-Dirac distribution, electron specific heat, Hall effect, thermal conductivity in metals; Bloch function, Fermi surface, Kronig-Penney model, Fermi surface. An Introduction to the Tight Binding model will also be covered. We will also investigate topics related to semiconductors (energy gap, carrier mobility, intrinsic and extrinsic semiconductors) and the pn junction. We will also be studying magnetic susceptibility, Hund's rules, Curie's law, hysteresis curve; Meissner effect, London equation; and the BCS theory.

Suggested Readings:

- Solid-State Physics: An Introduction to Principles of Materials Science. Ibach, Harald, Lüth, Hans. ISBN 978-3-540-93804-0.
- Ashcroft, N. W. and Mermin, N. D., Solid State Physics, Saunders, 1976.
- Kittel, Charles, Introduction to Solid State Physics, 7th Ed., Wiley, (1996).
- Myers, H. P., Introductory Solid State Physics, 2nd. Ed., Taylor & Francis, 1997.

Intended Learning Outcomes:

At the end of the course students should be familiar with:

- the basic concepts in condensed matter physics. It is useful for advanced courses in the field, but also to complete own preparation in physics.
- the physical basis of numerous contemporary applications of Solid State Physics

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Plasma Physics	Undergraduate Thermodynamics (APPH230) + Undergraduate Mathematical Physics (APPH322)
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Course Description:

This course covers the concept of plasmas along with various other topics including quasineutrality, occurrence of plasmas, charged particle motion and adiabatic invariants, microscopic and macroscopic description of plasma, classification of plasma, Magnetohydrodynamics, Alfven waves and magnetoacoustic waves, diffusion and resistivity of plasma. generalized Ohm's law, wave propagation in plasmas, plasma instabilities, Landau damping, the production and diagnostics of plasmas in the laboratory, technical plasma physics, thermonuclear fusion and plasma in space.

Suggested Readings:

- Fundamentals of Plasma Physics J. A. Bittencourt. ISBN-13: 978-0387209753.
- Fundamentals of Plasma Physics. Paul M. Bellan. ISBN-13: 978-0521528009.
- Introduction to Plasma Physics. R.J Goldston , P.H Rutherford. ISBN-13: 978-0750301831
- Principles of Plasma Physics for Engineers and Scientists. Umran S. Inan , Marek Gołkowski. ISBN-13: 978-0521193726.
- Introduction to plasma physics and controlled fusion. Volume 1, Plasma physics. Francis F. Chen. ISBN-13: 978-0306413322.

Intended Learning Outcomes:

After completing the course the participant should be able to:

- define plasma state, give examples of different kinds of plasma and explain the parameters characterizing them
- explain the concept of quasineutrality and describe plasma interaction with surfaces
- formulate kinetic and fluid descriptions of plasma, and understand the applicability of the appropriate approximations (ideal MHD, single fluid description, many fluid model).
- discuss plasma resistivity and diffusion in plasma based on the charged particle motion
- linearize equations describing plasma and derive differential equations for various types of waves in plasma and their dispersion relation
- explain the properties of the most important wave modes in plasma: dispersion relation, polarization and motion of the charged particles
- explain the concept of plasma instability, and analyze the instabilities based on the dispersion relation
- explain the use of thermonuclear fusion for energy production, and discuss problems with plasma confinement and current directions of research
- show understanding of plasma processed relevant for the near-Earth environment, interplanetary space and astrophysical objects

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Nanophysics: technology and advanced materials	Undergraduate Quantum Mechanics II (APPH432)
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Course Description:

This course will focus on nanomaterials' synthesis and technological developments. This is a multidisciplinary module. It explores science and technology at the nanoscale. We will study the physical properties of nanomaterials, the tools and techniques for nanosystem fabrication and investigation; principles of mechanical, optical, electrical, and magnetic nanosystems; current state of nanotechnology in physics and recent applications such as plasmonics.

Suggested Readings:

- Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, 2nd Edition. Edward L. Wolf. ISBN: 978-3-527-40651-7.
- Handbook of Nanophysics: Functional Nanomaterials. Klaus D. Sattler. ISBN: 978-1-420-07553-3.
- Handbook of Microscopy for Nanotechnology. by Nan Yao, Zhong Lin Wang. ISBN-13: 978-1402080036.
- Advanced Magnetic Nanostructures. by D.J. Sellmyer, Ralph Skomski. ISBN-13: 978-0387233093.
- Springer Handbook of Nanotechnology. Bhushan, Bharat. ISBN 978-3-642-02525-9.
- Nanotechnology and Nanoelectronics. Fahrner, Wolfgang. ISBN 978-3-540-26621-1.

Intended Learning Outcomes:

After completing this course students should:

- be able to critically evaluate nanotechnology concepts and therefore be equipped to delve deeper into nanotechnology research;
- demonstrate understanding techniques of microscopy for investigations on the nanometre and atomic scales;
- acquire knowledge of basic approaches to synthesize inorganic nanoparticles and their self-assembly in solution and surfaces.
- understand and describe the use of unique optical properties of nanoscale structures for analytical and industrial applications
- understand the physical and chemical properties of carbon nanotubes and silicon based nanostructured materials and rare earth doping.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Physics of Energy and the Environment	Undergraduate Modern Physics (APPH250)
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Course Description:

This graduate course will demonstrate the relevance of physics to topical issues of energy and the environment. The course discusses applied concepts and equations of physics in the mathematical description of energy transfer processes in natural energy sources and in energy technologies. Analysis of efficiencies of energy transfer will be included. The relevance of physics in understanding and improving energy technologies as well as assessing their environmental impact will be emphasized. Specific topics will include; first and second laws of thermodynamics, wind energy, Betz limit on efficiency of wind turbines, solar energy, semiconductor physics relevant to solar cells, radioactivity, nuclear reactors and nuclear waste disposal. A project towards the end of the course will lead students to writing a review on a topic chosen from eg. current ideas in improving efficiency in emerging energy technologies or Environmental impact of nuclear energy.

Suggested Readings:

- Environmental Physics: Sustainable Energy and Climate Change, 3rd Edition. Egbert Boeker, Rienk van Grondelle. ISBN : 978-0-470-66676-0.
- Physics of Solar Cells: From Basic Principles to Advanced Concepts. Peter Wurfel. ISBN: 978-3-527-40857-3.
- Energy and Environment. Loulou, Richard, Waaub, Jean-Philippe, Zaccour, Georges (Eds.). ISBN 978-0-387-25352-7.
- Foundations of Environmental Physics: Understanding Energy Use and Human Impacts. Kyle Forinash. ISBN: 9781597267090.
- Energy, Environment, and Climate. Richard Wolfson. ISBN-13: 978-0393912746.

Intended Learning Outcomes:

At the end of the course, students will be able to:

- quantify energy transfer and efficiencies in basic processes relevant to energy technologies.
- explain how knowledge from diverse areas of fundamental physics is used for progress in energy technology and in issues of environmental impact.
- perform informed manipulations of quantitative data in scientific articles on energy and related environmental issues.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Advanced Radiation Physics	Undergraduate Modern Physics (APPH250)
3	--	3		

Course Description:

This course covers topics including interaction mechanisms for electromagnetic radiation, compton scattering, photoelectric absorption, fluorescence, pair-production, charged particle interactions, concept of the stopping-power and the Bethe-Bloch formula, elastic scattering, neutron capture and photoneutron production. We will also investigate topics on radiation detection and dosimetry, mechanisms associated with the functioning of gas-filled ionization chambers, as dosimeters, as proportional counters and Geiger counters, Scintillation detectors and photomultipliers, semiconductor detectors and CCD cameras. Other topics including the generation of therapeutic radiation, megavoltage x-ray beams by linear accelerators and specification of beam quality, electron beams, Co-60 teletherapy, brachytherapy, kilovoltage x-rays will also be covered. We will also be studying the principles of dosimetry, the biological effects of radiation, the concept of radiation activity and dose, cavity theory and the determination of dose, the control of radiation exposure, radiotherapy, production of radionuclides and radiopharmaceuticals.

Suggested Readings:

- Radiation Detection & Measurement. Glenn F. Knoll. John Wiley & Sons, Inc. (2010) – 4th Edition. ISBN: 978-0-470-13148-0.
- Radiation Physics for Medical Physicists. Podgorsak, Ervin B., ISBN 9783642008757.
- Introduction to Radiological Physics and Radiation Dosimetry. by Frank Herbert Attix. ISBN-13: 978-0471011460.
- Walter and Miller's Textbook of Radiotherapy: Radiation Physics, Therapy and Oncology. By Paul Symonds, Charles Deehan, Catherine Meredith, John Mills. ISBN: 978-0-443-07486-8.

Intended Learning Outcomes:

Upon the completion of the course, student will be able to:

- understand radiation interaction mechanisms, the trends and their derivations for a range of materials
- understand the underlying principles of radiation detection
- understand the extension of these foundations to dosimetry, radiation protection and radiotherapy.
- have the ability to model radiation problems

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Health and Occupational Physics	Undergraduate Modern Physics (APPH250)
3	To be determined by instructor	3		

Course Description:

This course is comprised of lectures, tutorials and practical classes, some of which include field trips to measure natural/medical radiation. The course is designed to introduce the philosophy, protocols and practices of safety in the medical and industrial field, ensuring workplace health and safety requirements are met necessary to minimize hazards associated with radiation, electrical, mechanical and biological techniques. We will cover various topics including the history of safety provisions, responsibility and legislation, role of safety officer, medico-legal implications, causes of accidents and human error, hazard analysis and system safety planning, instrumental safety - dialysis, electrical hazards, electrical protection, and non-ionizing electromagnetic radiation hazards. Topics on the philosophy of radiation protection; absorbed dose, equivalent dose, effective dose, radiation weighting factors, organ weighting factors, stochastic and deterministic effects, recommendations on radiation dose limits, external and internal exposure, ingestion and inhalation, annual limits on intake, derived limits, codes of practice, potential exposure and constraint will also be covered. We will also investigate radiation protection in medical areas, patients and professionals, radiation protection in mining and milling of radioactive ores, radioactivity in soil, water, air and biota - pathway analysis, radiation protection in other professional situations, transport, disposal, storage and handling of radioactive materials.

Suggested Readings:

- Introduction to Radiation Protection. Grupen, Claus. ISBN 978-3642025860.
- Physics for Radiation Protection: A Handbook. James E. Martin. ISBN-13: 978-3527406111.
- Atoms, Radiation, and Radiation Protection. James E. Turner. ISBN-13: 978-3527406067.
- Introduction to Health Physics: Fourth Edition. Herman Cember , Thomas Johnson. ISBN-13: 978-0071423083.
- An Introduction to Radiation Protection 6th edition. Alan Martin, Sam Harbison, Karen Beach, Peter Cole. ISBN 9781444146073.
- Radiation Protection and Dosimetry: An Introduction to Health Physics. Stabin, Michael G. ISBN: 978-0-387-49982-6.

Intended Learning Outcomes:

On completion of this unit, you should:

- Be familiar with sources of ionizing and non-ionizing radiation.

- Have an understanding of the principles and applications of radiation protection as well as the recommendations concerning exposure of persons to radiation and noise.
- Be able to recognize counter measures to potential hazards and to institute safety awareness programs.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Quantum Optics	Statistical Physics (MPHYS524)
3	--	3		

Course Description:

The course introduces the student to the semi-classical description as well as to the full quantum theoretical description of the interaction between matter and nano structures. These methods are used to describe the light field in various quantum optical states and to describe absorption, emission and photo detection. We will work with the quantum optical description of interference and coherence as well as with noise phenomena in detectors and lasers. We will also study the generation and measurement of uniquely quantum optical phenomena such as squeezed light and entanglement. The student is also introduced to the quantum mechanical coupling between light and nano structures in optical micro cavities as well as applications of quantum optics in metrology and informatics. The student is thus introduced to the most current research in quantum optics.

Suggested Readings:

- Introductory Quantum Optics. Christopher Gerry, Peter Knight. ISBN-13: 978-0521527354.
- Quantum Optics, 3rd, Revised and Extended Edition. Werner Vogel, Dirk-Gunnar Welsch. ISBN: 978-3-527-40507-7.
- Quantum Optics. Marlan O. Scully , M. Suhail Zubairy. ISBN: 9780521435956.
- Quantum Optics: Including Noise Reduction, Trapped Ions, Quantum Trajectories, and Decoherence. Miguel Orszag. ISBN: 9783540727071.
- Quantum Optics: An Introduction (Oxford Master Series in Physics). Mark Fox. ISBN: 9780198566731

Intended Learning Outcomes:

A student who has met the objectives of the course will be able to:

- learn the quantum nature of light and the basics of photon statistics and interaction of light with matter
- become acquainted with the thoeretical and experimental methods of the field.
- understand the quantization of the electromagnetic field and apply this to describe the vacuum field as well as the coherence properties of optical quantum states.
- explain the properties of mixed and pure optical quantum states and calculate measurable quantities of such states.

- discuss different mathematical representations of quantum states of light such as the Fock state representation, the position representation and the Wigner function formalism.
- describe different measurement techniques in quantum optics such as homodyne detection and photon counting.
- explain the fundamental atom-light interaction using the semi-classical and the fully quantum mechanical approach (Jaynes-Cummings model).
- understand open, dissipative quantum systems and in particular cavity quantum electrodynamics.
- discuss how a quantum system can be protected from decoherence and disentanglement.
- discuss different optical elements that transform quantum states such as the beam splitter, the parametric amplifier and the phase plate.
- discuss and perform calculations on modern applications of quantum optics including quantum metrology, quantum information processing and quantum opto-mechanics.
- conduct and understand advanced experiments in quantum optics.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Shielding and Commissioning	Undergraduate Modern Physics (APPH250)
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Course Description:

A course covering the science of opening a new radiation oncology center covers shielding calculations, installing and running the acceptance testing of a linear accelerators, high dose rate brachytherapy remote afterloader, CT simulators, and treatment planning systems. It will also cover the commissioning of the treatment planning systems.

Suggested Readings:

- Shielding Techniques for radiation oncology facilities, Patton H. McGinley. ISBN-13: 978-1930524071
- Radiation Shielding. J. Kenneth Shultis , Richard E. Faw. ISBN-13: 978-0894484568.
- A. E. Profio, Radiation Shielding and Dosimetry, Wiley-Interscience, 1979.
- A.B. Chilton, J. K. Shultis and R.W. Faw, Prentice-Hall, Principles of Radiation Shielding.
- NCRP Report No. 144, Radiation Protection for Particle Accelerator Facilities, 2003.
- NCRP Repot No. 147, Structural Shielding Design for Medical X-Ray Imaging Facilities.
- NCRP Report No. 151, Structural Shielding Design and Evaluation for Megavoltage x-Ray and Gamma-Ray Radiotherapy Facilities, 2005.

Intended Learning Outcomes:

At the end of this course the students should be able to:

- comprehend the details in shielding calculations for a linear accelerator vault, HDR suite, and CT simulator, involving cost effective decisions while the radiation protection is ensured at a maximum level.
- commission a treatment planning system, and the record and verify network.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Medical Imaging	Undergraduate Modern Physics (APPH250)
3	To be determined by instructor	3		

Course Description:

This course is comprised of lectures, tutorials and practical classes, some of which include visits to clinical centers. This course presents the fundamental principles of medical imaging techniques such as magnetic resonance imaging (MRI), X-ray, computed tomography (CT), ultrasound (US), positron emission tomography (PET), and single photon emission computed tomography (SPECT). For each of these imaging modalities its physical principle, the mathematical methods for image generation and reconstruction, its anatomical and physiological information content and its limitations are discussed.

Suggested Readings:

- Farr's Physics for Medical Imaging. Penelope Allisy-Roberts, Jerry R. Williams. Elsevier Health Sciences, 2007. ISBN: 9780702028441.
- The Essential Physics of Medical Imaging. Jerrold T. Bushberg. Lippincott Williams & Wilkins, 2002. ISBN: 9780683301182.
- Medical Imaging: Physics of medical imaging, Parts 1-2. John M. Boone, Martin Joel Yaffe, Michael J. Flynn (PhD.), Richard L. Van Metter, Jacob Beutel, James Talmage Dobbins, American Association of Physicists in Medicine, SPIE Digital Library. SPIE, 2004.
- Physics for Medical Imaging Applications. Yves Lemoigne, Alessandra Caner, Ghita Rahal. ISBN: 9781402056499.
- Medical Imaging Physics. William R. Hendee, E. Russell Ritenour. John Wiley & Sons, 2003. ISBN: 9780471461135.

Intended Learning Outcomes:

After taking this course the participants will have a basic understanding in the following areas:

- know the fundamental criteria of medical imaging and have a basic understanding of medical image processing
- know the basic physical and technical principles for the generation of medical images, especially for conventional x-rays, x-ray computed tomography, medical ultrasound, nuclear imaging and magnetic resonance tomography
- know the basic mathematical principles for the generation of tomographic medical images

- be able to explain the most important imaging artifacts in typical medical images acquired with the discussed modalities
- know typical applications for each of the discussed medical imaging modality

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Monte Carlo Methods in Physics	Computational Physics (MPHYS625)
3	To be determined by instructor	3		

Course Description:

This course is comprised of both practical sessions and lectures. The instructor will decide on the number of practical exercises in the form of practical sessions and homework. The course provides a practical introduction to Monte Carlo methods in physics, Monte Carlo integration, pseudorandom number generators, sampling, scoring, and precision, Markov chain Monte Carlo, application of Monte Carlo methods to solve numerical equations in physics involving linear operators, the fundamentals of the physics of radiation transport, and applications of Monte Carlo simulations to classical and quantum systems and radiation transport.

Suggested Readings:

- Markov Chains: Analytic and Monte Carlo Computations. Carl Graham
- Handbook of Monte Carlo Methods. Dirk P. Kroese, Thomas Taimre, Zdravko I. Botev
- Monte Carlo Methods in Statistical Physics. M. E. J. Newman , G. T. Barkema

Intended Learning Outcomes:

After completed course, the student should be able to:

- apply various Monte Carlo techniques, such as the simple sampling, control variants, correlated sampling, stratified sampling and importance sampling, in solving various mathematical and physical problems.
- program and choose a generator or pseudo-random and quasi-random sequences.
- interpret and evaluate the results of statistical nature.
- master the theory behind the Monte Carlo simulation of radiation transport in matter.
- master the fundamentals of the physics of radiation transport, and applications of Monte Carlo simulations to classical and quantum systems and radiation transport in linear accelerators.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Special Topics in Physics	Undergraduate Modern Physics (APPH250)
3	--	3		

Course Description:

Subject matter to be selected by instructor and students on an ad hoc basis in specific areas at the master's level.

Intended Learning Outcomes:

In addition to the specific knowledge imparted, students develop skills in critical thinking about physical situations, problem solving and quantitative analysis.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Methods of Experimental Physics	Undergraduate Modern Physics (APPH250)
3	To be determined by instructor	3		

Course Description:

This course is comprised of lectures and practical classes, some of which include experimental data processing, analysis and presentation. The course is based on the modern approach of information theory. It presents novel experimental techniques, tools, and data processing methods for physics applications. It shows students how to plan and perform experimental investigations, data processing, and interpretation.

Suggested Readings:

- Methods of Experimental Physics. Mikhail I. Pergament. ISBN 9780750306089
- Experimental Physics: Modern Methods. R. A. Dunlap. ISBN-13: 978-0195049497
- Statistical Methods in Experimental Physics: 2nd Edition. Frederick James. ISBN-13: 978-9812705273.
- Probability and Statistics in Experimental Physics. Roe, Byron P. ISBN 978-1-4684-9296-5

Intended Learning Outcomes:

At the end of the course, students should:

- be familiar with the methods of experimental data processing
- have an integrated understanding of the general properties of measuring systems
- be able to critically evaluate the relationship between theory and experiment, find the sources of disagreement and suggest further development of theory or experiment to improve understanding of the difference.

	Weekly Hours		Course Name	Prerequisite
Cr.	Practical	Lecture	Advanced Computational Fluid Dynamics	Computational Physics
3	To be determined by instructor	3		

Course Description:

In this class, students will get an overview of the modern state of computational fluid dynamics while taking a detailed mathematical look at several important CFD topics. Concepts that are developed in class will be applied in a series of programming-based homework assignments and projects. We will study several discretization methods, including the finite volume method, the finite element method, and the hybrid control volume finite element method (CVFEM), while discussing numerical modeling concepts (like conservation and stability) that are common to all methods. Specific physical modeling topics that will be covered are turbulence modeling (include basic turbulent flow physics, Reynolds averaged models, and Large Eddy Simulation), and techniques for modeling flows with moving boundaries and fluid-structure interaction.

MPHYS601 SEMINAR 1

Advanced study of a topic related to physics, as determined by the Program Council. Writing a research report and presenting it in class. This course is offered to comprehensive exam track students.

MPHYS602 SEMINAR 2

Advanced study of a topic related to physics, as determined by the Program Council. Writing a research report and presenting it in class. This course is offered to comprehensive exam track students.