COURSES OFFERED BY THE DEPARTMENT OF FUNDAMENTAL PROBLEMS IN TECHNOLOGY

BASIC SCIENCE COURSES

1)FZP009386W Modelling of physical processes and phenomena using Computer Algebra Systems 30w

prof. dr hab. Antoni C. Mituś W11

Computer algebra systems offer advanced mathematical tools for a simplification of both symbolic and numeric calculations in research studies of a student and scientific worker. The goal of the course is to teach the PhD student how to use chosen mathematical methods (derivatives, integrals, ordinary differential equations, partial differential equations, variational calculus and linear algebra) offered by computer algebra system *Maple* and to use those methods for a practical solving of chosen problems in mathematical physics like, e.g. linear and non-linear oscillators, phase portraits of dynamical systems, chaos and others.

2) Advanced signal and data processing 30w

dr hab. inż., Iskander Robert, prof. nadzw. (W11)

The course includes, in the first part, the introduction to data and signal processing, deterministic signals, time and frequency domains, linear systems, and the construction of digital filters. In the second part, the course includes, random signals, the notion of non-stationarity, spectral analysis, coherence function, time-frequency space, estimation and signal detection. In the final phase of the course, advanced methods of signal processing deviating from classical methods are considered, taking into account issues such as empirical mode decomposition, matching pursuit or the bootstrap method.

3)FTP9008 Statistics in biomedicine 30w

dr hab. inż., Iskander Robert, prof. nadzw. (W11)

The course covers the methods of statistical analysis applied to medical and biomedical sciences. It covers such issues as descriptive statistics, normality testing, non-normal distributions, least-squares estimation, maximum likelihood estimation, regression analysis, parametric and non-parametric hypothesis testing, jackknife and bootstrap methods

4) Nanomaterials: properties and applications 30w

dr hab. Grzegorz Sęk, prof. nadzw.

The lecture will concern various aspects of modern nanotechnology, from methods of nanomaterials' fabrication, nanoengineering and post-growth processing, through development of investigation methods in the nano scale, to description of unusual physical properties. The course will also include a review on the history of nanotechnology and related

sciences, and cover many classes of nanomaterials as: semiconductor quantum dots and nanocrystals, photonic micro and nanostructures, nanometals and plasmonic structures, nanofibers, carbon-based nanomaterials, including graphene and carbon nanotubes, two dimensional materials based on chalcogenides, polymers and nanofibers, organic nanomaterials, porous materials and low-k dielectrics, composites and nanoconcrete, and many others. There will especially be elaborated all the issues related to current applications and future application prospects in such branches as photonics and optoelectronics, electronics, mechanical and civil engineering, transport and communication technologies, etc.

5) Concepts of Modern Physics 30w

prof. dr hab. inż. Paweł Machnikowski, prof. dr hab. Antoni C. Mituś

The course is oriented at non-physicist PhD students interested in the so-called modern physics. The course covers the following topics: quantum theory (fundamentals and contemporary problems), nuclear physics, elementary particles and the standard model of fundamental forces, the quest for unification, elements of astrophysics, cosmology (history and space-time geometry of the Universe). The level of the course is adjusted to the participants.

SPECIALIZED COURSES

1) FTP9009 Inorganic Nanomaterials For Bio-medical and Optoelectronic Applications 30w

dr hab. inż., Podhorodecki Artur, prof. nadzw. W11

The main aims of the course are: to learn and to understand the physical phenomena occurring in inorganic nanostructures of various types (quantum dots, rods, plates etc.), to learn and to understand modern manufacturing techniques of nanomaterials (PVD, CVD, wet chemistry), to learn about the most recent applications of nanocrystals in biology medicine and optoelectronics.

The main millstones of the course are following: Introduction and nanomaterials classification. Basics of solid state physics and low dimensional structures – general overview. Physical phenomena in colloidal inorganic nanostructures (excitons, plasmons, carrier multiplication, emission blinking, bleaching, hopping transport). Inorganic nanostructures – synthesis methods (PVD, CVD, wet chemistry). Inorganic nanostructures – surface engineering (functionalization and bio-conjugation). Applications of inorganic nanostructures in biology and medicine. Applications of inorganic nanostructures in optoelectronics (LEDs, PV cells)

2) FTP9012 Introduction into Photovoltaics 30w

prof. dr hab. Ewa Popko W11

The solar energy emitted by sun-free and non-carbon has driven scientists for decades to develop photovoltaic devices (PV) solar cells that catch sunlight and convert it directly to electricity. Today, the solar po uction into photovoltaics Popko Ewa, dr hab, prof. nadzw. PWr. 30wwer industry is manufacturing and installing solar modules worldwide at record-setting numbers. In the lecture the review on the PV state of art will be given. In the introductory part of the lecture the attendee will get knowledge about fundamentals of solar radiation. The solar cell's working principle will be explained. Next, solar cell performance, parameters and standard design will be described. Silicon solar cells have dominated PV market since 1954 and currently claim about 90% of the solar-cell market. These solar cells belong to the most matured 1st generation solar cells (wafer based crystalline and multi-crystalline silicon and GaAs solar cells). Due to the economy, the II-nd generation of solar cells emerged in search for cheap, efficient solar cells. Thin film solar cells: amorphous silicon, CdTe, CIGS and CIS solar cells, kesterites belong to this class of PV solar cells. Emerging photovoltaic technologies based on dye-sensitized solar cells, organic compounds, perovskite materials, and quantum dots garner intense coverage in the science press. These types of solar cells III-rd generation of PV solar cells-sit in the spotlight because they promise to be less expensive and well suited to many more applications than conventional. But where do these emerging photovoltaic technologies stand today? Are they limited to university research labs? Are they being developed by technology incubators and start-up companies? What is the state of art of solar cells' research and development (R@D) and the road map of PV market?

3) FZP009086W Expanding Universe 30w

prof. dr hab. inż. Andrzej Radosz W11

This course is divided into the three parts. In the first part, the story of the Big Bang hypothesis is presented. It starts from the so-called "night sky paradox" (XVIII/XIX c.) that

could not be solved within classical physics approach. It was resolved in the 20's of the XX c. due to the Hubble's discovery: "recession of the galaxies" and due to the theoretical proposal, FLRW (Friedman-Lemaitre-Robertson-Walker) approach, formulated within General Theory of Relativity (GTR). The key element was G. Gamov's (1948) idea. It was an idea of a very hot early universe dominated by radiation, then followed by a cold universe dominated by matter. The transition between these two was accompanied by the release of black body radiation. The discovery of such a radiation (1965), so-called "relic radiation" (or CMB - Cosmic Microwave Background) ended the controversies concerning the universe: homogeneous and isotropic Universe is expanding according to the Big Bang scenario

(developed within GTR). In the second part we present and discuss thermodynamic and dynamic aspects of expanding universe. The only time-dependent quantity in this scheme is a scale parameter and it is inversely proportional to the temperature of CMB. Big Bang scenario is then presentedas a history observed backward in time: starting from a current "galaxy" era, one reaches a separation instant followed by radiation dominated phase. The early stages in a very dense and very hot universe are: a lepton's era, a hadron's era, electro-weak unification,

a “desert” range, GUT and an inflation era. The earliest stage is the so-called Planck’s era: one reaches an initial, quantum stage of expansion where space and time arrived. In this part of the course we discuss the related questions of entropy and matter-antimatter asymmetry. The question of the origin of the elements is presented: in the expanding universe only two first elements, hydrogen and helium were formed. The other elements were formed due to star evolution (and decay).In the third part of the course we discuss the problems of accelerating expansion. The key feature for the expansion within closed, open or flat scenario is a value of the energy density. In the light of the recent discoveries this quantity involves apart of a luminous matter component also exotic dark matter quantity and even more intriguing component, dark energy. Facts and hypothesis concerning those features are presented.

4) FTP9003 Microscopic studies in Biomedical Engineering 30w

dr hab. Marta Kopaczyńska, prof. PWr. W11

The interdisciplinary course for PhD students from different faculties concerns an advanced level of development trends and the most important new developments in the field of microscopy methods for the study of the cells and biological materials. Particularly, the following modern nanoscopic imaging techniques will be presented: fluorescence microscopy (STED, PALM STORM), multi-photon microscopy, FRET, FLIC, TIRFM, FLIM, atomic force microscopy (AFM), transmission electron microscopy (TEM) and techniques of nanomanipulation such as optical tweezers.

5) FZP9384 Elementary introduction into stochastic processes for physicists and engineers
prof. dr. hab. Antoni C. Mituś W11

The aim of the course is to introduce basic concepts of stochastic processes for a non-mathematically oriented PhD student. Students will learn how to model and analyze statistical properties of chosen well-known physical systems in the presence of additive and multiplicative noise driven by Wiener process. The following topics will be discussed: Brownian motion, Wiener-Levy process, Langevin equation and Ornstein-Uhlenbeck process, Fokker-Planck and Smoluchowski equations, Ito’s calculus. Chosen applications in physics will be discussed like, e.g., diffusion, Brownian projectile, stochastic harmonic oscillator, stochastic cyclotron motion, elastic scattering. Theory will be illustrated with practical examples in a computer laboratory.

6) INP9014 Advanced Algorithmic Techniques 30w

prof. dr hab. Mirosław Kutyłowski W11

The course "Advanced Algorithmic Techniques" is devoted to advanced paradigms for constructing effective algorithms. An overview of diverse methods is given, in most cases substantially different from the algorithms devoted for the traditional von Neumann model. The course covers topice such as parallel computing, distributed algorithms, communication complexity issues, randomized methods, rapid mixing, decision diagrams, quantum computin

g and computations for uncertain data. Together with effective solutions, lower bounds for complexity of computational problems are discussed.

7) Great discoveries in physics 30w

dr hab. inż. Marcin Motyka

This lecture is focused on twelve, or maybe more, most important discoveries in physics, as chosen by the lecturer, which revealed the nature of the world we live in. During the cycle of lectures, the people responsible for the greatest discoveries will be introduced by assorted tales of their scientific and personal lives. Every discovery will be supported by the detailed description of the experiment that has led to it, sometimes accidentally, but always - successfully changing the understanding of the Universe operation principles. Lectures start with fundamental discoveries which for instance brought to light the existence of gravity, electricity and magnetism. Afterwards, last century discoveries will be revealed, including the principles of quantum mechanics (e.g. uncertainty principle or quantum Hall effect), high temperature superconductivity, the nature of the time (twin paradox and time dilation), nanomaterials fabrication (quantum dots, graphene etc.) and their application to development of the transistor, solar cell and laser. Finally, the latest discoveries regarding gravity waves detection, in respect to cosmic background radiation and determination of the age of the Universe, will be delivered.

8) Physics of sound and music 30w

dr hab. Paweł Scharoch

The lecture is designed to be an informal scientific bird-eye view on sound and music. Starting from fundamentals of vibrations and wave physics, through the key phenomena (resonance, energy transport, diffraction, interference, standing waves), the focus will be put on the acoustic waves, their characteristics (acoustic pressure, intensity, speed), sources (including human voice), propagation and detection. In particular, the detection of sound by human ear and perception in the brain, together with some basic physiological mechanisms, illustrated by images from modern techniques of an investigation into brain functioning (neuroimaging) will be discussed. The lecture will then concentrate on the music sound. Its basic features will be characterized: pitch, volume and timbre. In that context, the construction of chosen musical instruments will be presented and physical mechanisms of sound generation described, together with historical aspects of instruments development. In the following parts, the mathematical structures of musical scales and keys, and their evolution over history will be presented. The main elements of music (tones and chords, melody and harmony, beat and meter, rhythm and tempo, dynamics, texture, and others) will be explained and illustrated by music samples (live and audio-video). On that basis, some examples of music genres will be featured. Then, an interesting issue of psychological aspects

of music perception will be discussed (emotions, moods, music in movies), as well as new discoveries in the field of brain biology (the effect of music on brain development and regeneration, music therapy in brain diseases). Finally, the modern technologies in the world of music will be briefly described (digital representation and electronic generation of a sound, music recognition, the role of the internet, etc.). During all the course a lot of historical references will be given, as well as references to other parts of physics, in particular quantum physics, and the references to sound physics in other fields (whispering gallery, strings). Advanced mathematical tools used for describing some of the discussed phenomena and systems can be shown as an option.

9) Nonlinear oscillations and waves 30w

dr hab. Andrzej Janutka

The course is devoted to the most popular models of nonlinear dynamics and their applications. It covers basic solutions and their analysis. Details of the solutions in terms of the Hirota (direct) method of the soliton theory are provided.

Content:
1: Duffing oscillator (basic solution, stability points, periodic forcing, transition to chaos)
2: Van der Pol oscillator (basic solution, periodic forcing)
3: Lottka-Volterra (predator-prey) model
4: nonlinear Schrodinger equation (direct solutions, solitons and their collisions; asymptotic analysis, applications)
5: Manakov (Vector nonlinear Schrodinger) equation (polarized solitons and their collisions)
6: Korteveg-de Vries equation (the first soliton problem in history)
7: sine-Gordon equation (applications to quantum optics, superconductivity, …, soliton solutions)
8: stationary sine-Gordon equation in 2D (applications to thin magnetic films, domain wall solutions, vortex and antivortex solutions, comparison to vortices of Poisson equation)

10) Elements of sociophysics 30w

prof. dr hab. Katarzyna Weron

During this course I will present a modern interdisciplinary applications of statistical physics, which are aimed to deepening our understanding of the complex social systems. The course will cover the following subjects: introduction to agent-based modelling of social systems, the idea of Monte Carlo simulations, elements of modern theory of critical phenomena and phase transitions that are used in sociophysics, elements of non-linear dynamics as a tool for investigating systems at macroscopic level, complex networks, models of opinion formation and other social processes.

INTERDISCIPLINARY SEMINARS

1)FTP9013 Current Research in biomedical sciences

dr hab. inż., Kotulska Małgorzata, prof. nadzw. W11 15s

The seminar is focused on presenting the cutting-edge science in biomedical , biophysical, and biochemical sciences , theoretical and experimental. By the assumption, the course scope is very broad and invites PhD students from different faculties, however each edition will put special impact to topics within interest of the students currently participating in the class. The course participants will present a seminar and lead a discussion related to the topic in English. The course will also include talks from distinguished senior scientists who are experts in these fields who will be invited by the class instructor

2)FTP9014 Current Research in biomedical sciences B

dr hab. inż., Kotulska Małgorzata, prof. nadzw. W11 15s

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3)FZP009393S Scientific literature seminar 15s

prof. dr. hab. Antoni C. Mituś W11

The PhD student will acquire and improve the skills of oral presentation in English language of the results of scientific research (his/her own or from scientific literature) and will master the basic techniques of oral presentation at international conferences. The student will give a short (a few minutes) oral presentation at each meeting, followed by a short discussion motivated by the lecturer. The presentation will be evaluated by the audience and the lecturer.

4)FZP009394S Scientific literature seminar 2 15s

prof. dr. hab. Antoni C. Mituś W11

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5) MDP009001S Biomedical Engineering in Personalized Medicine: Prediction and Prevention 15s

prof. dr hab. inż. lek.med Halina Podbielska, W11

Currently, predictive, preventive and personalized medicine (PPPM) is in focus of many authorities worldwide, including the EPMA - the European Association of PPPM. It is known

that the same therapeutic approaches may lead to individual outcomes. For many acute and chronic disorders, the current healthcare outcomes are considered as being inadequate: global figures cry for preventive measures and personalised treatments.
In fact, severe chronic pathologies such as cardiovascular disorders, diabetes and cancer are treated after onset of the clinical symptoms and even at near end-stages. Pessimistic scenario considers pandemics for type 2 diabetes mellitus, neurodegenerative disorders and some types of cancer over the next 10–20 years followed by the economic disaster of healthcare systems in a global scale.
Advanced healthcare needs a change from reactive to predictive medicine tailored to the person, from delayed intervention to preventive medicine and from disease care to holistic healthcare.
The cost-effective management of diseases and the central role of PPPM in modernisation of healthcare have been prioritised by global (UNO, WHO, EC, other), as well as regional organizations and health-related institutions.
The new concept in the healthcare sector that enables to predict individual predisposition before onset of the disease, to provide targeted preventive measures and create personalised treatment algorithms tailored to the person is in focus of this course.

6) MDP009002S Biomedical Engineering in Personalized Medicine: diagnostics and therapy 15s

Prof. dr hab. inż. lek.med Halina Podbielska, W11

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