GGSB Meeting @HZDR - QUALI-Start-Up Lectures

Sunday 17 August 2025 - Saturday 23 August 2025

Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Book of Abstracts

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Motion of electron near black hole

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We consider a black hole metric in which the spacetime outside the event horizon is rotating with a constant angular velocity. From this metric, we derive the equations of motion. We then calculate the radii of the light cylinders—two real solutions arising from a cubic equation (the third being complex and unphysical). We also identify the radii corresponding to steady (circular) orbits. Using this information, we assign a physical interpretation to each radius and describe the nature of the associated orbits. Finally, we calculate the maximum energies that an electron can attain in this spacetime, taking into account relevant constraining factors and compere this results to maximum energies of electrons with Schwarzschild's metric.

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High precision, managed thermostatic chamber

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Thermostatic chambers are frequently used to examine how different device characteristics are affected by changes in temperature. This report describes the development of such a chamber using primarily locally available components. The system provides both heating and cooling for the internal space. It utilizes digital temperature sensors to ensure precise temperature control. A voltage-controlled converter was designed to regulate the power supplied to the heating and cooling elements. The entire system is managed by a Raspberry Pi single-board computer. A slow-control system, implemented in Python and based on a PID algorithm, enables rapid adjustments to the internal temperature according to the desired setpoint and maintains thermal stability over time. To improve usability, a web-based interface has been created for remote temperature monitoring and PID parameter configuration.

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Computational Modeling of Aircraft Flight and Machine Learning-Based Control

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In this presentation, I will talk about general computational flight mechanics, general methods of simulating flight using different tools like Python3 (simulations and mathematical modelling), OpenVSP (CFD), and Python libraries like SciPy and NumPy. I will explain how these tools can be used to

model aircraft and simulate flight, using the most basic numerical methods. Furthermore, I will cover how the data generated from these simulations can be utilized to train machine learning models for autonomous flight control, using frameworks like PyTorch or TensorFlow. I will also talk about my goals and plans for this research, including future steps like simulating real 3D flight and adding image processing. I plan to apply these methods to real-life situations, especially for controlling unmanned aerial vehicles (UAVs). This work demonstrates the potential of combining physics-based modeling with machine learning to advance autonomous flight.

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CNB assisted DE model

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Neutrino oscillations require massive neutrinos and therefore some new physics beyond the Standard Model of Particle Physics. The most stringent upper bound on the sum of neutrino masses comes from the cosmological observations. Assuming the hierarchical mass spectrum, this upper bound in the case of normal ordering is about 0.06 eV and in the case of inverted ordering it is around 0.01 eV. On the other hand, the present CNB temperature is estimated to be of the order of 10−4 eV. Thus, one may conclude that one or two neutrino species of CNB are going to be non-relativistic at present. In natural units c = $\hbar$ = 1, the energy scale associated to the present DE density, (ρ0 DE)1/4, is quite close to the heaviest neutrino mass. This fact may look suggestive to consider the coupling between the DE and neutrinos in the hope that one may naturally address the present DE density and matter density coincidence issue. The mechanism is based on the the possible back-reaction of CNB on the quintessence field when neutrinos enter the non-relativistic regime. Because of this back-reaction the scalar field rolling down the effective potential slows down and effectively plays the role of the cosmological constant. Since this transition to the non-relativistic regime of CNB took place just in the resent past one may associate this time-scale to the activation of DE and this way resolve the coincidence issue. This crude statement is usually argued by saying that the factor ρν − 3pν in the equations of motion is almost vanishing for ultra-relativistic neutrinos while it becomes appreciable once neutrinos become non-relativistic. Thus one may expect to have a natural trigger of new dynamics that gets activated once the CνB temperature drops below the scale mν . In most models, however, the effective potential (that the field ϕ experiences) develops a minimum which evolves adiabatically and thereby provides us with an approximate solution. This minimum may capture the field much before the neutrinos enter the non-relativistic regime indicating the failure of this argument. We are looking for the model that would allow us a natural realization of the above idea.

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Investigation of isotope effect using supercritical fluid chromatography coupled with tandem mass spectrometry

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The aim of the present study was to develop a method using supercritical fluid chromatography and tandem mass spectrometry (SFC-MS/MS) that would enable the separation of isotopologues from each other on both, chiral and achiral chromatographic columns using amphetamine, its derivatives and analogs as examples.
The conducted experiments demonstrated that a strong isotopic effect is achieved during the analysis of methamphetamine and its deuterated derivatives —specifically, a baseline separation was obtained when using various chiral and achiral columns in combination with supercritical fluid chromatography.
The nature of the isotopic effect (normal or inverse) depends on the chemical composition of the selector, the mobile phase and the structure of the compound. On some chiral columns we observed a correlation between the isotope effect and enantiomeric separation.

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Particulate Matter in the Atmosphere

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One of the major ecological issues of the modern era is atmospheric pollution with particulate matter (PM).
The atmosphere, in connection with the rest of the Earth's other geospheres (hydrosphere, lithosphere, biosphere), forms a stable and yet dynamic ecological environment for the planet.
The development of civilization leads to changes in the balance between this stability and dynamism, shifting the impact from a local scale to regional and even to global ones.
In the case of the atmosphere, one such impact is the increase in the concentration of anthropogenic particulate matter in it, that is particularly evident in anthropogenic landscapes, especially in large urban areas, where the constant monitoring of PM's in the air, now recognized as a key air quality parameter, has become a pressing issue of agenda. The theoretical part of this work provides a general overview of the nature of microparticles, their origin and pathways of migration, as well as their impact on ecology - affecting both the living and non-living nature.
The experimental part of the work aims to demonstrate the predicted differences in the quantity of microparticles in the air within a single megapolis, between a densely populated urban area under intense anthropogenic influence and a recreational zone.
In addition, the study compares data obtained using a scientific-grade GRIMM laser aerosol spectrometer with data obtained by a low-cost, easily accessible sensor operating on a similar principle: Laser PM Sensor, Model: SDS011.

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Nanochemistry for Medicine

Author: Mariam Kenkadze[None]

Nanotechnology represents one of the most significant scientific advances of the 21st century, with nanoparticles offering unique physicochemical properties due to their high surface area-to-volume ratio. As the demand for efficient drug delivery systems increases, nanomaterials have emerged as promising tools, particularly in addressing challenges like antimicrobial resistance (AMR). Phage therapy, a potential alternative to antibiotics, faces several pharmacological barriers before reaching widespread clinical application. This research project aims to synthesize and characterize silica nanoparticles of varying diameters and investigate their interaction with a UN bacteriophage. Specifically, we assess whether co-incubation with nanoparticles affects the phage's plaque-forming ability. This study represents an initial step toward enhancing phage therapy through nanotechnology-based approaches.

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Design and development of a six-legged walking hexapod robot

Author: Nika Durishvili[None]

This project presents the development of a hexapod robot engineered for dynamic, terrain-adaptive locomotion and stable horizontal posture control. Equipped with 18 serial bus servos and controlled by an ESP32 microcontroller, the system implements real-time inverse kinematics and feedback-driven gait generation. A dedicated PID controller maintains balance across the horizontal plane during walking and uneven surface traversal. The robot communicates wirelessly and supports flexible gait strategies, enabling precise and coordinated leg motion for advanced mobility. The system features closed-loop control and is designed for practical deployment in legged robotic applications.

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Digital Clock

Author: Nikoloz Kalichava[None]

The task lies in the following: a digital clock that displays the time 7-segment with the help of an image output. Quartz generator at 32768Hz, part to be processed in the microprocessor will be to correctly calculate the time from the alignment from the circuit. Clocks, minutes and seconds will be measured with a maximum of 6 7-segment images. (Hours 0-23, minutes 0-59, seconds 0-59). With the buttons it will be possible to straighten the time. Main part of my project is usage of Digital components (Shift registers, Demultiplexer) and Microcontroller part: Clock, Timer and program code. This project was an initial experience with microcontrollers and digital components, selected to facilitate understanding of microcontroller programming and the interaction between the various components used.

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A Marine Oil Spill Collection Device

Author: Saba Ebanoidze[None]

This course project focuses on developing a portable oil spill recovery system that can be deployed from small vessels to clean contaminated ocean surfaces using mechanical methods. The main goal of this project was to develop a simple, effective design capable of rapidly containing and recovering oil spills before they could spread over large areas. This is especially important because oil spills pose severe threats to marine ecosystems, harming wildlife and causing long-term environmental damage. The system combines four main components: a surface-skimming funnel, a pump, a centrifugal separator, and an oil collection setup. The funnel was designed using CAD software, exported as an STL file, and 3D printed. Testing in a controlled environment showed successful visual oil recovery using a water-oil mixture, demonstrating the feasibility of the concept. This prototype highlights core mechanical engineering principles: fluid mechanics and density based separation, while addressing a critical environmental issue. Future improvements will focus on automation, wave stabilization, and scaling for real-world applications.

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Evaluating viability of zeolite as a methane capture device in enclosed/semi-enclosed cattle farms

Author: Nika Kikvadze[None]

Methane emissions from livestock in enclosed or semi enclosed environments represent a significant contributor to greenhouse concentrations, and can pose potential safety hazards, even though their half-life is quite short compared to carbon dioxide their impact is still noticeable, but apart from their dangers methane can also be useful as an energy source. This presentation aims to assess viability of zeolite or other porous materials in methane capture and regeneration to be used as an energy source in rural areas.viability is evaluated by simulating methane flow from cattle in farms and also looking at molecular simulations of zeolite and how it performs when exposed to methane, while also presenting a theoretical prototype system that can be incorporated into barns.

Parallel Session A: Physics topics & Interviews / **85**

Solar Wind magnetosphere coupling during the 2024 Geomagnetic storms

Author: Luka Tsulukidze[None]

Geomagnetic storms pose a threat to both technological systems and human health, making them a crucial area of research. In this study, we analyze the interaction between the solar wind and the magnetosphere during the strong geomagnetic storms of 2024 (March 3, March 24, and May 11). The research is based on the horizontal component of Earth's magnetic field (H) from the Dusheti Geomagnetic Observatory, alongside solar wind parameters such as pressure (P), plasma beta (βp), also the interplanetary magnetic field (Bimf) and its components (Bx,By,Bz). Special attention is given to the May 11, 2024 storm, the most powerful in over two decades. Cross-correlation and wavelet coherence analyses revealed significant correlations and distinct coupling structures for each storm. Notably, plasma beta (βp) was observed to rise sharply approximately 12 hours before a storm's commencement. By applying a 12-hour time shift to this parameter, we identified significant coherence in the 10 to 30-hour period range, suggesting its potential as a predictive tool. Detrended Fluctuation Analysis (DFA) captured shifts in the system's dynamics, showing drops in the Hurst exponent (indicating more noise like behaviour) during the storms of March 23 and May 11. In this work, we also investigate the multifractal nature of the global SYM – H and AL indices to better characterize their complexity and compare them to local geomagnetic field fluctuations. This study validates the reliability of local geomagnetic data for understanding the local response during the global space weather events in Georgia. The findings can aid in the improvement of geomagnetic storm forecasting models.

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Quadruplexes in DNA nanotechnology for non-enzymatic nucleic acid diagnostics

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Quadruplexes are highly structured forms of DNA consisting of stacked guanine tetrads linked by hydrogen bonds, which require the presence of cations, positively charged ions, such as potassium. Their high stability has made quadruplexes a good candidate for the development of new and effective diagnostic methods. Using quadruplexes, an isothermal diagnostic method for the detection of nucleic acids has been developed, called quadruplex primer amplification (QPA). It is an exponential

reaction similar to the polymerase chain reaction (PCR) using DNA polymerases, where the advantage of QPA lies in its isothermal nature. Our current research is focused on the development of an isothermal and non-enzymatic diagnostic method, which would be quite practical for the point-of-care (POC) diagnostics that involves conducting diagnostic research at the patient's site. This method is based on structural transformations between a hairpin (a duplex with the ability to form a loop) and a quadruplex. Hairpin, which contains a quadruplex forming sequence and the fluorescent nucleotide - 2-aminopurine (2AP) in the loop, opens in the presence of a pathogen and then instantly folds into a quadruplex, after which 2AP produces the appropriate fluorescent signal. This method will make it possible to isothermally and non-enzymatically diagnose any DNA/RNA of interest.

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Chaotic motion of a pendulum

Author: Alesandro Nonikashvili[None]

This research paper investigates a dynamic system that falls under the domain of nonlinear mechanics, specifically examining a pendulum setup that reveals complex and fascinating motion patterns. While the system may appear simple at first glance, it is shown to exhibit chaotic behavior, meaning that its future state cannot be precisely predicted beyond a certain point in time. This unpredictability arises from the sensitive dependence on initial conditions—a hallmark of chaotic systems. Due to the intricate and nonlinear nature of the system, the study moves beyond traditional analytical methods and instead relies on numerical modeling and simulation techniques to explore its behavior. This computational approach allows for a more detailed and flexible analysis, especially when dealing with the nonlinearity and sensitivity inherent in chaotic systems. Throughout the research, various system parameters were systematically altered in order to understand how and under what conditions chaos emerges. These variations provided insight into the transition between regular and chaotic motion and helped identify key thresholds and behaviors within the system. As a result, the study offers a deeper understanding of how chaotic dynamics manifest in pendulum motion and contributes to the broader understanding of complexity in nonlinear dynamical systems.

Parallel Session A: Physics topics & Interviews / 91

Obtaining various magnetic fields with a two-dimensional system of currents

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The importance of magnetic fields in modern physics is great, and mankind has known for a long time how a moving charge creates a magnetic field. That is, if we know the coordinates and velocities of charges moving in space or the current density at every point in space, then we can determine what the magnetic field induction is and where it is directed at any point.
The difficulty of analytically solving this problem depends on the system of currents that creates the magnetic field we are looking for, but the way to solve the problem is quite straightforward, and using Bio-Savar's law, even with a numerical method and therefore with a small error associated with it, we can always determine the magnitude and direction of the magnetic field induction at some point.
Here I will try to solve a special case of the inverse problem. The inverse problem involves not finding the magnetic field, but finding the system of currents: magnitudes, directions and locations, to obtain the desired magnetic field. I think the task in this regard has quite a practical content: "Tell us what kind of magnetic field you need and we will find the appropriate arrangement of currents." Unfortunately, we are not able to solve the problem at such a level that we can get the desired ⌧

(□,□,□) at any (□,□,□) point of the space.
To make the task analytically solvable, we must narrow the search spectrum, thus, as the title tells us, we will consider such a system of currents, which is placed in one plane. We will try to determine what kind of fields we can get and, if possible, analytically find the “backward path”, that is, if possible, on the contrary, show the currents by means of a magnetic field.