**COURSE SYLLABUS - IGF PAN**

1. Course title: Hydromagnetic dynamo theory in geo- and astrophysics 1 and 2

2. Course lecturer: dr hab. Krzysztof Mizerski

3. Discipline, field, year of studies: Magnetism (Fluid dynamics), Geophysics, all years

4. Course character: lecture 30h and exercise classes 30h, both semesters.

5. Teaching method: stationary, at the Physics Faculty, University of Warsaw

6. Language: English

7. Course type and number of hours: lecture 30h and exercise classes 30h, in each semester (60h of lectures and 60h of exercise classes in total, during the whole year)

8. Estimated amount of student's independent work: 70 h

9. Total workload and number of ECTS points: 6 ECTS for each semester

10. Short description and main focus of the course:

    FIRST SEMESTER:

    1. History of theories describing the generation of the geomagnetic field.
    2. The Earth's dynamo compared to the dynamo on other objects of the solar system (the Sun, Mercury, Venus, Jupiter's moon Io, Jupiter and Mars, the Moon in the past). Why is the Earth Dynamo still so effective?
    3. Magnetohydrodynamics equations
        a. Navier-Stokes equation with Lorentz force
        b. Maxwell's equations
        c. Derivation of the equation of the magnetic field induction
        d. Helmholtz theorem of the frozen magnetic field.
        e. Taylor-Proudman theorem
    4. Mechanisms of magnetic field generation
        a. Omega effect and alpha effect - mean field theory.
        b. Dynamo type alpha-Omega and alpha^2
        c. Magnetic instabilities - magnetorotational instability and instability of magnetic buoyancy in the context of the Solar Tachocline.
        d. Tidal instability (source of the magnetic field on Io).

    SECOND SEMESTER:
    Theoretical description of Convection in natural systems
    1. Boussinesq approximation
    2. Anelastic approximation
    Waves in the Earth's core – dispertion relations and physical properties. Observed geomagnetic oscillations.

3. Methods used in the study of geomagnetic variations.
4. MAC waves
5. Torsional waves
6. Rossby waves
7. Inertial waves

Comparison of observations and theory. What has been explained and examples of important problems still waiting be resolved.

11. References, literature, online resources:

Literature: The lecture will not be fully based on any particular book and its aim will be to present complex issues related to the hydromagnetic dynamo in an accessible form. Therefore, there is no single textbook, but the recommended literature includes (will be sent to students in electronic form):

[1] P. Roberts 1967, An introduction to magnetohydrodynamics, American Elsevier Pub. What.

[2] H.K. Moffatt and E. Dormy 2019, Self-exciting fluid dynamos, Cambridge University Press,

[3] K.A. Mizerski 2021, Foundations of Convection with density stratification, Springer

[4] IUGG, 2020, Geomagnetism, Aeronomy and Space Weather, Eds. M. Mandea, M. Korte, A. Yau, E. Petrovsky, Cambridge University Press.

12. Educational outcomes including PQF level 8 codes:

Students will learn about the origin of the terrestrial and other astrophysical magnetic fields; they will gain knowledge about the favourable conditions for vivid dynamo action in natural systems and why the geomagnetic dynamo is surprisingly efficient when compared to other rocky planets in the Solar system; various aspects of the dynamics of the plnateray and stellar interiors will be explained; P8U_W, P8U_U.

13. Evaluation of the educational outcomes:

Students will be required to complete one task per semester to pass - written report on a given topic. The topics of these tasks will be presented during the first lecture - there will be topics to choose from. Some will be descriptive, others more mathematical.
In addition, passing an oral exam will be required.

14. Criteria to complete the course:

Completing one of the tasks and at least 3 on the exam.