Prof. dr hab. Aleksander Brzeziński
Faculty of Geodesy and Cartography
Astronomy and Geodesy Observatory
Warsaw University of Technology

Title of the course:

Introduction to the theory of Earth rotation

Summer semester 2015
ECTS points: 3
Schedule: Mondays at 16.15-19.00, room 226 WUT Main Building, Pl. Politechniki 1
Total: 30h
The lectures will be held if any foreign student is enrolled, if not – the reader will make a decision of a language
Examination Terms: exam, necessary final grade

Short description

Theory of Earth rotation has been recently considered as one of three pillars of geodesy, besides the subjects of the shape and gravity field of the planet. There are several reasons for that such as: 1) In the epoch of common use of the observations of artificial satellites it is necessary to know the time variable transformation matrix between global terrestrial and celestial reference frames, which in turn can be considered as a parameterization of Earth rotation. 2) The Earth orientation parameters (EOP) depend on the shape, internal constitution and rheology, as well as on the dynamical properties of our planet. The time variability of EOP's appear to be a sensitive indicator of global changes taking place in the fluid layers of the Earth, the atmosphere, the ocean, the land hydrology and the liquid core. 3) The use of the space geodetic techniques – very long baseline interferometry VLBI, satellite and lunar laser ranging SLR/LLR, and global navigation satellite systems GNSS – increased dramatically the accuracy of EOP determination from about 30 milliarcseconds (mas) in 1970-ties to 0.05 mas, which in turn became a challenge for the modelling and interpretation efforts.

This course offers a systematic and modern introduction to the theory of Earth rotation, formulated according to the recent standards and conventions. It begins with general considerations concerning the kinematics and dynamics of the rigid body moving in space, then the description is specified for the Earth by taking into account the parameters of its figure and the model of external gravitational influences. The equations of motion are derived in the linear form, then is computed the solution in the closed form. In the second part of the course the theory is refined by taking into account the deformations of the Earth. It begins with general description of the dynamics of a deformable body which is then split up into translation, rotation and deformation. Then introduced is the model elastic deformations and the corresponding equations of motion. The last part of the course is devoted to the problem of modeling the atmospheric and oceanic influences on Earth rotation.

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It is assumed that the participants of the course have a basic knowledge of the mechanics, the complex number arithmetic, the linear algebra and the theory of the ordinary differential equations.

Program details:

1. General information – historical overview, recent knowledge and observations, reference systems and parameterization of Earth rotation, modeling of Earth rotation, parameters of models.
2. Kinematics of rotation of the rigid body in space – translational motion and motion relative to the center of mass, definition of the rotation vector
3. Dynamics of rotation of the rigid body – the inertia tensor, external torque, angular momentum, conservation law of angular momentum, kinetic energy.
4. Rotation of the rigid Earth – Euler dynamical equations and their free and forced solutions, geometrical interpretation of solutions.
5. Parameterization of Earth rotation – reference systems, definition of the axes and poles of rotation, angular momentum and the dynamical figure, kinematical relationships, polar motion and nutation of the rigid Earth.
6. Principles of analytical dynamics and their application for description of rotation of the Earth in space – generalized coordinates, Euler angles, Lagrange equations, theory of Woolard.
7. Dynamics of motion of a deformable body – decomposition into translation, rotation and deformation; momentum, angular momentum, torque, equations of motion, kinetic energy; definition and properties of the Tisserand axes.
8. Rotation of the deformable Earth – perturbation model, Euler-Liouville equations, tidal and rotational deformations, figure axis of the Earth.
9. Elastic deformation of the Earth – Love numbers, polar motion: free and forced solutions, Chandler period, geometrical interpretation of the solutions; precession-nutation; variation of the length of day l.o.d. and the universal time UT1, perturbations by the zonal tides and the corresponding solution.
10. Atmospheric perturbations of Earth rotation and their modeling – excitation functions, angular momentum approach and the torque approach, loading deformations, effective angular momentum functions of the atmosphere, estimation and interpretation, modeling the ocean response to the atmospheric pressure variations; oceanic and hydrological perturbations.
11. Selected recent problems of the theory of Earth rotation – relationships between the coordinates of the rotation vector and the coordinates of the Celestial Intermediate Pole CIP; observation, modeling and a search for the excitation mechanism of the free Chandler wobble.

Bibliography

Brzeziński A. (2005). Modelowanie precesji-nutacji jako ważny element badań globalnej dynamiki Ziemi, *Osiągnięcia Nauki i Techniki – Kierunki Rozwoju i Metody, Konwersatorium Politechniki Warszawskiej, red. merytoryczny S. Janeczko*, wkładka nr 4 do Miesięcznika Politechniki Warszawskiej nr 3/2005, in Polish.

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KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

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Zharkov V. N., S. M. Molodensky, A. Brzeziński, E. Groten and P. Varga (1996). *The Earth and its Rotation: Low Frequency Geodynamics*, Herbert Wichman Verlag, Hüthig GmbH, Heidelberg.

About the lecturer

Prof. Dr. Aleksander Brzeziński is a full professor at the Faculty of Geodesy and Cartography of the Warsaw University of Technology. He got the Master Degree in mathematics at the University of Warsaw in 1977, the PhD degree in 1986 and the habilitation in 1991 from the Institute of Geophysics of the Polish Academy of Sciences. In 2000 he received from the President of the Republic of Poland the title of Professor of the technical sciences.

Prof. Brzeziński is one of the leading specialists in the theory of Earth rotation, author or co-author of over 100 research papers including the book “The Earth and its Rotation: Low Frequency Geodynamics”. He is a member of the International Astronomical Union (IAU) and of the IAU Commission 19 „Rotation of the Earth”. He was elected the Vice-President of C19 (term 2003-2006) and the President of C19 (2006-2009). He is a member and of the International Association of Geodesy (IAG). Currently he serves as Vice-President of the Commission 3 of IAG „Earth rotation and geodynamics”. He participated in the works of 8 study groups or working groups dealing with different problems of the theory of Earth rotation. At present it is the “IAU/IAG Joint Working Group on Theory of Earth Rotation”, in which he is the leader of Sub-Working Group 2 „Polar Motion and UT1”.

Prof. Brzeziński received several prizes for his scientific achievements. The most important is the European Union Descartes Prize 2003 for his contribution to the international project „Non-rigid Earth nutation”.

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