ECOLOGY IN ENGINEERING EDUCATION

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***Abstract* — *Crisis in relationship between nature and society is being increased. Perspectives of humanity development are connected not only with improvements of civilization but also, in a greater extent, with a crucial change of the proper civilization. Future engineer as a promoter of technical progress must realize the need of care towards the nature and our planet. At present many specialists from different areas of knowledge are involved into issues of ecology. The subject of Physical Ecology deals with study of natural and man-made physical phenomena (electromagnetic fields, corpuscular irradiation of the sun, Earth's magnetic field, atmospheric electricity, radioactivity, sound and vibrational oscillations etc.) and their impact on human being. Physics of Environment as a discipline has been developed and delivered in a form of lectures for the students of various engineering specializations.*

Index Terms* — *Ecology, Ecological Physics, environmental protection.

INTRODUCTION

The rapid crisis in the relationship between nature and society is ever growing and it is the education that has a challenge to stop it. The perspectives of humanity development are related not only to a technological improvement of its civilization but also to the crucial change of a proper civilization paradigm as well as to reconstruction of a human spiritual world and to the change of its scale of values. A human being has to change his self-estimation as a conqueror of the nature; now he should strive for being a room-mate of the surrounding world. He has to learn how to secure their mutual evolution and his co-development with the nature [1].

A modern man must learn to see the world in its integrity. A future engineer as a driver of technological progress is obliged in first turn to realize the necessity of his careful attitude towards the nature, our planet, the earth's bowels, atmosphere, rivers, lakes, seas and oceans. It is necessary to inculcate in a future technical specialist from the very first steps of his engineering formation the skills of the right estimation of the impact of his technological solutions on the environmental medium. In this connection, the students of all specialization in MADI Technical University are obliged to attend during one semester the course "Industrial and Transport Ecology" [2].

At present many various specialists are concerned with the issues of ecology: from physicists, chemists, biologists to engineers, lawyers, sociologists, political scientists etc. Studies of physical fields (electromagnetic, acoustic, vibrational) of natural and man-made origins, their influence upon human being and environments constitute the subject of *Physical Ecology* [3].

PHYSICAL ECOLOGY AS A SUBJECT

In 2002, at INTERTECH'2002 Conference in Santos I presented my report about the course *"Ecological Physics"* intended for the students of the 4th year whose future specialization should be *Engineer-Ecologist* [4, 5]. In 2003 the course *"Physics of Environment"* will be presented to your attention. The course has been prepared and delivered by the author to the students of the 2nd year whose specialization is *"Automobile Service"*. Based on concepts of modern Physics, this course is intended to give to the future engineers the notion of natural processes, Earth's properties, its atmosphere, lithosphere, hydrosphere that create the conditions in which the humanity and environments were being developed [5-10].

The syllabus of the course *"Physics of Environment"* is intended for 36 lecture hours. Its structure:

I. Introduction. Backgrounds of Cosmology.
II. Gravitational interaction.
III. Electromagnetic interaction.
IV. Composition and structure of Earth's atmosphere.
V. Contemporary problems of ecology.
VI. Energy pollution of environment.
VII. Conclusion.
VIII. Literature.

In *Introduction* the basic principles of cosmology are given: the Big Bang theory, age, evolution and structure of the universe. The hypotheses of formation of Solar system, planets and their satellites are considered. Data about the planets composition, their densities, masses, distances to the sun and periods of revolution are also given. A problem of mass and angular momentum distribution between the sun and planets is discussed. The physical research methods applied to the universe such as spectrum analysis of celestial objects radiation, Doppler effect for *Red shift*, Hubble's law, hypothesis of expanding or pulsing universe are also considered.

Chapter II deals with gravitational interaction, the law of universal gravity and the Earth's shape. The Earth's gravitational field is considered in the context of its anomalies and variations with the altitude. The gravitational energy of a sphere-like body is calculated. The notion of gravitational radius is then introduced and its value for Earth and Sun calculated as example. The average density observable of the universe gives rise to estimate its gravitational radius. The

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latter is compared with its dimensions. A possibility of *black holes* formation and attempts to discover them is a subject for vivid discussions.

The motion of planets and comets is considered in details and Kepler's Laws are derived from equations of motion and equations for angular momentum. The peculiarities of Earth's satellites motion are explained. Here, it is worth saying how the observable trajectories of satellites provide with means to correct the information about the Earth's shape. The influence of Earth's atmosphere on satellite braking is considered. The optimum trajectories of interplanetary cruises as well as the parameters of geocentric orbits for space communication satellites are calculated. The lunar and solar tides on Earth are explained with comparison of their scale and significance. A possibility to build the power station using the energy of tidal waves appears to be a good topic for general discussions. The Earth's nutation is also considered.

One of most interesting topics here is the use of seismic data to study the inner structure of the Earth. It is important to underline here that one of founders of seismology as a science (which was formed at the beginning of the 20^{th} century) was Prince Boris Golitsyn (1862-1916), Russian physicist and geophysicist, Academician of Imperial Academy of Sciences in St. Petersburg. It is explained here that the velocities of longitudinal and transverse waves traveling through the Earth during an earthquake depend on Earth's density. Owing to this fact the Earth's crust, Moho's boundary, Earth's mantle and Earth's inner nucleus have been discovered.

Besides, it is worth discussing the fact that the Earth cannot be treated as an inertial frame of reference because of rotation around its axis and that an introduction of so called *forces of inertia* is necessary to describe the motion of bodies in Earth's reference frame. A centrifugal force of inertia is responsible for change in weight of a body when measured at different latidudes. The force of Coriolis is to be taken into consideration when the motion of rockets, projectiles and air masses of atmosphere are calculated.

Chapter III considers the electromagnetic interaction beginning with the elementary particles classification based on a type of interactions in which the particles participate (photon, leptons, hadrons). A short historical reference is given on the development of knowledge about electric and magnetic phenomena beginning with ancient Greek concepts up to the laws of electrodynamics and quantum mechanics. The development of knowledge about Earth's magnetic field is given in full details. A comparative table for values of magnetic induction of Sun, planets and Moon is given in a context of importance of the magnetic field for life of living things on the Earth. The quantitative parameters to describe the magnetic field are provided (vector of magnetic induction, intensity of magnetic field, its horizontal component, magnetic declination and inclination). The *SI* units of measurement *Tesla (T)* and *Amper/meter (A/m)* are compared with *Gauss* and *Oersted* prevalently used in the past. The hypothesis of the Earth's magnetic field formation is considered. The value for the magnetic induction at poles, equator, middle latitudes are given. As a subject for discussion the issue of the constant component and variations of magnetic field is raised. Brazil (Rio de Janeiro) and Siberia are given as examples of magnetic anomalies. Paleomagnetic measurements, magnetic field inversions, linear magnetic anomalies and a hypothesis about broadening of the oceanic bottom appear as the good subjects for further discussions with students.

Topics about the Earth's electric field begin with quantitative characteristics known from *General Physics* course: intensity and potential of electrostatic field and units of their measurement. The Earth's charge is then calculated starting from known values of the electric field intensity in the vicinity of the Earth. Some values of electric field intensities typical of natural phenomena are given (a good weather field, a field in the channel of lightning electric discharge). The formation of positively and negatively charged ions in the atmosphere is also considered.

This last point leads to the motion of charged particles in electromagnetic fields. Its consideration begins with the equation of motion in stationary electric and magnetic fields under action of Lorentz's force when the parameters of trajectories are calculated. The drift of particles in crossed electric and magnetic fields is also considered with an emphasis that the drift velocity does not depend upon the mass of a particle or its value and sign of charge. The drift in a non-uniform magnetic field is an interesting point which helps to comprehend the action of magnetic mirrors. The Earth's radiation belts and their role in life processes are considered together with the motion of particles in alternating electromagnetic fields.

The differential wave equation is then derived on the basis of Maxwell's equations. The expression for the velocity of an electromagnetic wave in vacuum and in media is given.

The atmosphere's composition and structure are studied taking into account the altitude. It is shown that the presence of troposphere, stratosphere, mesosphere, thermosphere and exosphere is determined by the change of temperature with the altitude. The regions of homosphere and heterosphere are considered in the context of atmosphere's composition. The impact of "small" gases upon the atmosphere's status, weather and climate is discussed. The physical reasons for change of the atmosphere's composition with the altitude in heterosphere find their full explanation. The standard model of Russia's atmosphere serves as an example. Some more complicated formations – ionosphere, magnetosphere and protonosphere – accomplish this topic.

The impact of the Sun on atmosphere's composition and structure is studied together with its astronomic data, its radiation power and temperature of its photosphere, chromosphere and corona. The energy spectrum and absorption bands of Earth's atmosphere together with the indication of absorbent gases are given. The basic laws of heat radiation are also revised (Kirchhoff's, Stefan-Boltzmann's, Wien's shift, Planck's Law of heat radiation). The basic processes of absorption of electromagnetic radiation by the atmosphere are subject for discussions (resonant absorption, photoelectric effect, Compton's effect). The Earth's energy balance is a subject of particular interest. Here we calculate the solar constant, the Earth's temperature and estimate how this temperature is affected by so called "greenhouse" effect.

Next step is the thermodynamic processes in atmosphere. Here we consider how the pressure and the density of air depend upon the altitude (in isothermic and adiabatic approximations). The Boltzmann's formula is then derived. The adiabatic temperature-altitude gradient is calculated and compared with its value obtained experimentally. The thermodynamic stability of the atmosphere is also discussed.

Studies of atmosphere's dynamics are conducted taking into account the action of the force of Coriolis on air streams. The processes of formation of cyclones and anticyclones and of geostrophic wind are explained as well as some traditional historic maritime terms ("roaring forties", "horse latitudes" etc.). The atmosphere's global circulation system is considered (Hadley's cell, Ferrel's cell, polar anticyclone, western transfer, North-Eastern trade-wind). The particular values of energy for powerful tropical cyclones, hurricanes and typhoons are given. The essence of some local winds finds here its physical interpretation and explanation: coastal and seaside breeze, monsoon, mistral. Some attention is paid to meteorological parameters and atmospheric phenomena which determine the physical state of the atmosphere the weather depends on. The climate is considered as "Synthesis of weathers". Then we consider a scheme of a mean radiation and thermal balance of atmosphere and a possibility to predict the weather: beginning from skilled meteorologists of the past and further towards the modern forecasting science based upon mathematical models of atmosphere and ocean. Speaking about models we consider deterministic and statistic methods of calculations. Points of bifurcations are also considered. The problem of global warming takes a particular place in student discussions. All contemporary ecological problems are considered from the point of view of the anthropogenic impact on environment. We consider the "greenhouse" gases of natural and man-made origin in the context of their role in global warming. The Earth's climate is considered in its ambiguity as a subject which may have different stationary states. The solar activity is considered in its action on atmosphere and biosphere.

The ozone problem is taken seriously as one of the most important problems. The following issues are considered in this topic: physical and chemical properties of ozone; absorption of UV radiation by ozone atoms; ozone concentration in the atmosphere; processes of ozone molecules formation and disintegration; chlorine-fluorine carbohydrates and their role; ozone holes. International efforts to decrease atmospheric emission of impurities which disintegrate ozone are presented.

The problem of energy sources is presented as one of the most crucial problems of humanity. For the sake of comparison we present a table of energy values for the following cases:

- gravitational interaction of Earth's particles;
- rotation of Earth;
- heat streams through the Earth's surface;
- Moon's tidal influence;
- earthquakes;
- volcanic eruptions;
- energy of falling rocks and soil erosion, avalanches, tornados, cyclones;
- energy of large power stations;
- energy liberated due to nuclear explosions, rocket start accidents, big fires at oilfields and refineries.

We draw a conclusion that the energy of man-made processes is comparable with that of large geophysical processes. The basic forms of energy influence on environment are brought to light and the ways to solve this problem are considered. The next point is the ways to save energy by means of resources-economy and energy-economy technologies. New cleaner ways to produce energy are considered. In this context we compare the rate of energy produced by power stations of different types: thermoelectric, hydroelectric, atomic. We compare their efficiencies, atmospheric emission, raw materials consumed and prospects for future. Non-traditional sources of energy are also welcome for discussion: solar power engineering (based on photoelectric and thermodynamic transformers and bioconversion of solar energy), wave engineering (with active and passive transformers of wave energy and energy concentrators), tidal power engineering (with its experimental set-up and discussions on advantages and drawbacks of working and anticipated power stations), geothermal power engineering (working stations and their prospects).

Energy pollutions of environment are considered next. Here we consider noise, vibrations, electromagnetic fields and radiations. The elastic waves are studied beginning with the process of propagation of sound oscillations in air. In adiabatic approximation the differential wave equation is derived and the dependence of velocity of elastic waves in a gas on pressure and density is determined. The notion of sound pressure is introduced and its relationship with the vibrational velocity of medium's particles is established. The energy carried by an elastic wave is then calculated and Umov's vector introduced. The intensity of sound wave is then expressed via the sound pressure amplitude and the amplitude of vibrational velocity. Other relevant issues are specific acoustic resistance of a gas, Law of Weber-Fechner, level of sound loudness and units of its measurement, limits of sound audibility and sensation of pain. Some examples of sounds having different levels of intensity are given. A problem of human ear sensibility with relation to different frequencies is discussed and the level of sound pressure (in *A* scale, *dBA* units) estimated. Other kinds of sound noise are also considered.

Next topic is man-made electromagnetic fields and radiations including their impact on human health. A particular accent is made on using cellular telephones. Some means of effective protection are considered. The ionizing radiation (UV, X and radioactive sources) are considered in the context of their impact on human health (ionizing activity, dosimetry, units of measurement, radiation background etc.).

The "grand total" is in the conclusion of the course: collective knowledge is necessary to solve the ecological problems on the Earth and it is the engineers who are to solve this problem.

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