Physics and Engineering (LTFY.01.007)

Objectives:

The main goal of the course is to introduce the role of physics in the generation of the individual's personal physical concept of the Nature and to explain the fundamental physical principles of modern technologies.

Learning outcomes

Upon completion of this course, the student should be able to:

1. Express the basic principles of the physical concept of the world (such as atomistic principle, energetic minimum, absolute speed, wave-particle duality, uncertainty principle), and refer to their exertion;
2. Possess the knowledge considering the mathematical background and calculus necessary for the description of physical processes (e.g., graphical representations, differentiation and integration, application of complex numbers), and recognize the main attributes and occurrence conditions of main functions present in physics (power, exponent, harmonic etc);
3. Know the physical quantities describing the most important natural phenomena and properties including their abbreviations and measuring units; recognize the reasonable order of magnitude of physical quantities.
4. Use the vocabulary introduced at the lectures to explain the basic principles of some high-tech devices applying physical terminology in a correct way;
5. Solve the physical problems within the limits of example exercises available via the web support of the course.

Brief description of the course:

The course is targeted to the quick and efficient introduction of the main principles of the current physics (matter and field, fermions and bosons, absolute speed, energy minimum, etc.), whereas the previous knowledge in physics is not required. In most important cases, the examples are illustrated considering the application of the mathematical methods in physics (differentiation, integration, complex numbers). The students also learn to explain the operating principles of selected technical devices applying physical terminology in a correct way.

Schedule of the course (fall semester 2018):

1. **Introduction and general principles of physics.** Basic concepts of scientific method: hypothesis-verification, problem-finding. Models and laws in physics. Measurement and units. Properties of the substance and field. Interactions: gravitational, electromagnetic, weak and strong. Properties of the Nature and physical quantities describing them. Standard model: fermions and bosons. Energy minimum. Absolute speed (speed of light). Linear and angular momentum. Spin of the particle. Pauli exclusion principle. Wave-particle duality. Scalars and vectors. Uncertainty principle. Relation with mathematical formalism: power and exponential functions. Half-life and time constant. Exponential decay, limited exponential increase, sine and cosine functions. Complex numbers, Euler formula. (Lecturer: Sven Lange, 07.09-24.09)
2. **Mechanics.** Motion, position and displacement, coordinate systems, frame of reference, velocity, acceleration. Graphical representation and equations of motion. Differentiation and integration in physics. The time derivative operator and the operator of defined integral over time. Newton's laws in the case of translational motion. Momentum and energy, their conservation laws. Work and power. Friction force, coefficient of friction. Drag force. Rotation. Coordinate angle, angular velocity and angular acceleration. Normal acceleration. Centripetal and centrifugal forces. Vector and scalar products. Examples: torque and work. Rotational inertia, angular momentum. Newton's laws in the case of rotational motion. Precession and the gyroscope. Conservation of the angular momentum. Elasticity, Hooke's law. Buoyancy, Pascal principle, static and dynamic pressure, Bernoulli equation. Tensile, shear and uniaxial stresses and strains. Young modulus, shear modulus and bulk modulus. (L: Sven Lange, 28.09 – 19.10)

3. **Oscillations and waves.** Periodic motions, amplitude, displacement and phase. Simple harmonic oscillations, velocity and acceleration, energy of oscillations. Damped oscillations, forced oscillations and resonance. Exponential decay and damping constant. Complex representation of the oscillatory motion. Waves in the Nature. Transverse and longitudinal waves. Wavefunction. Interference and diffraction. Standing waves, harmonics, Fourier Transform. Soundwaves intensity and sound level. The Decibel Scale. (L: Kalev Tarkpea, 22.10 - 02.11)
4. **Electromagnetic field.** Electrostatics. Coulomb's law, electrostatic field. Field lines. Field strength E, voltage and electric potential. Magnetostatics. Ampere's law for current-carrying wires. Magnetic flux density B. Electric current. Ohm's law and Joule's heat. Resistance and resistivity. Dielectrics and magnetic materials. Permittivity and permeability of matter. Electric displacement D and magnetic field strength H. Gauss law for the electric and magnetic flux. Ampere's law for the magnetic field lines. Uniform electric and magnetic fields. Lorentz force. Electromagnetic induction. Electromotive force (EMF). Faraday's law of induction. Lenz's law. Maxwell-Faraday equation. Principles of the electric motor and generator. Self-induction and inductance. Eddy currents. Displacement current. Maxwell's equations. Electromagnetic oscillations and waves. (L: Kalev Tarkpea, 05.11- 23.11)
5. **Quantum mechanics and optics.** The scale of electromagnetic radiation. Spectral parameters: wavelength, wavenumber, frequency and quantum energy. The emission and absorption of light according to the Bohr model. Spectral series of the hydrogen atom. Modern model of atom. Orbitals, quantum numbers. Basic principles of quantum mechanics. Wave-particle duality and Heisenberg uncertainty principle revisited. Wave function and Schrödinger's equation. Tunnelling. (L: Kalev Tarkpea, 26.11 - 03.12). Thermal radiation and luminescence. Propagation and absorption of light. Reflection and refraction. Wave optics: polarization, diffraction and interference. Quantum optics: photoelectric effect, interaction of light with matter. Laser light and its applications. Nuclear physics: radioactive decay, nuclear reactor. Thermonuclear fusion. (L: Sven Lange, 07.12 and 10.12)
6. **Electrical and optical engineering.** Intrinsic and doped semiconductors. P-N junction. Diodes, LED's, semiconductor lasers and transistors. JUGFET and MOSFET. CCD and CMOS technologies. (L: Sven Lange, 14.12). Capacitance and inductance. Alternating current. Inductive and capacitive reactance. Phase relation between voltage and current, phasor representation. Electric motors, generators and transformers, electromagnetic data communication. (L: Kalev Tarkpea, 17.12)
7. **Molecular physics and thermodynamics.** Temperature and heat. Three states (phases) of matter and phase transitions. Molecular forces, surface tension. Main concepts of kinetic theory of gases. Laws of the thermodynamics. Heat engines and refrigerators. (L: Kalev Tarkpea, 21.12).

Study aids:

1. Study aids available on the home page of the course https://sisu.ut.ee/pae/
2. D. Halliday, R. Resnick, J. Walker. Fundamentals of Physics. Extended version. 5-th and the later editions. Wiley.

Assessment methods and criteria 2018

With four written test during semester, the student can collect 70% of total points of final examination. The first two tests can give up to 15% and the last two tests as 20% of the final score, respectively. The rest 30% can be collected with the final written examination. In order to qualify for examination the student have collect at least 35 points from a sum of four tests (i.e., half or more of the possible 70 points). The positive completion of all the tests is not required in order to qualify for the examination; however, it will be required for full completion of the course. The first test will assess the achievement of the first learning outcome and third outcome from the aspect of mechanics and oscillations. The three last tests will assess achievement of the fifth learning outcome (physical problem solving ability). The achievement of the third learning outcome related to the chapters of electromagnetic field, optics and quantum mechanics will be assessed during the written examination.

In order to get a positive final score for the whole course, a student has to get over 50% in all four tests as well as in the each of the final exam tasks assessing achievement of the learning outcomes 2, 3 and 4. They are the Functions task, the Physical Quantities task and the Engineering task. The last one can be substituted by compilation of the report (at least 5 pages) about the working principle of some chosen engineering device. The ultimate deadline for presenting the written report which substitutes the engineering task of the exam is the 7th of January 2019. After this day, the 4th learning outcome can be assessed only by successful completion of the engineering task (no written reports will be accepted).

The additional oral part of the examination can be arranged for students who scored initially over 70% of the final score, in order to provide them a possibility for the improvement of the final result. There will be two chances for passing each test during the semester and they do not depend on the time of performing the attempt. The students are invited to perform the some written test only if they are trained enough via the web-based system Moodle. In order to qualify for examination the students have collect at least 35 points from a sum of four tests during the semester (50% or more of the maximally possible 70 points). If the positive result of some outcome-assessing examination task is already reached, there is no need to do this task again. All the reached positive results are valid. On the resit the student may confine only to the problems he/she failed on the first examination. There is no need to wait for the official resit day at the end of January. All the students who are able to perform some outcome-assessing task are invited to show their ability immediately on the nearest examination day. If the only one or two learning outcomes remain negative (not reached) at the end of written examination period then the student can briefly complement his/her written task on the additional oral part of the exam to reach the positive final assessment. All the examination procedure ends before the start of the next semester and the students who have already remaining negative results of the outcome-assessing tasks have failed. They should repeat the course on the next year.