COURSE DESCRIPTION CARD - SYLLABUS

Course name
Mechanics [S1IBio1>MECH]

Course

Field of study
Biomedical Engineering

Year/Semester
1/2

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
15

Other (e.g. online)
0

Tutorials
15

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

The student starting the course should have a basic knowledge in mathematics and physics at the first cycle study level. He should have the ability to understand and interpret the acquired knowledge, and also to effective self-education and be ready to cooperate within a team.

Course objective

Cognizing and understanding the main concepts and laws of mechanics. Developing skills in modeling of mechanical systems and in solving problems related to the movement and the equilibrium of the mechanical systems.

Course-related learning outcomes

Knowledge:
1. The student who completed the course knows and is able to explain the main concepts in the area of engineering mechanics. He also knows the basic laws of mechanics and is able to write them using mathematical formulae and explain them in detail.
2. He has the knowledge in the field of engineering mechanics which allows for formulating and solving static and kinematic problems and formulating dynamic problems of mechanical systems.

Skills:
1. The student can formulate and solve the equilibrium equations.
2. He is able to make the structural analysis of simple multibody systems and determine the velocities and the accelerations of elements of these systems also.
3. He can derive the equations of motion of the particle, formulate the appropriate initial conditions and to solve the problem.
4. He can formulate the laws related to change of the momentum and the angular momentum for free and constrained mechanical systems.

Social competences:
1. The student understands the importance of knowledge in the modern world. He is also well aware that the rapid development of knowledge causes the need for lifelong learning.
2. He is able to think and act in a creative way.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Learning outcomes presented above are verified as follows:
Lectures: Exam in writing involving practical and theoretical issues. The exam tasks are rated on a point scale. 50% of the total points is needed to pass the exam.
Tutorials: Tests in written and assessment of the activity on classes. Both assessment components are rated on a point scale. To pass the classes the student needs at least 50% of total points.
Laboratory classes: Short texts in written and assessment of self-solved problems using Mathematica program. Credit for a positive grade after obtaining at least 50% of the total points..

Programme content

Elements of vector calculus.
Introduction to statics and dynamics - a force as a model of interactions between bodies.
Systems of forces. Equivalent force systems. The force-and-couple resultant of a system of forces.
Statics. Equations of equilibrium. Constrained material systems. Constraints. Equilibrium of a system of interacting bodies.
Kinematics of a particle. Description of the motion of a particle in the Cartesian coordinate system.
Description of the point motion in the natural coordinate system (the Frenet coordinate system).
Kinematics of a rigid body. General motion of a rigid body. Translational motion, rotational motion and plane motion of a rigid body.
Dynamics of a material particle. Direct and inverse problems of the dynamics of material particle.
Inertia properties of material systems. Inertia tensor. Euclidean transformations of the inertia tensor.
Dynamics of a free and constrained material systems. Dynamics of a rigid body. Momentum, angular momentum, and kinetic energy.

Course topics

Lectures: Subject of mechanics. Movement. Reference frame. Material particle and rigid body as models of real bodies in theoretical mechanics. Physical quantity. Scalar and vector quantities in mechanics.
Elements of vector calculus. Right-handed Cartesian coordinate system. Decomposition of a vector.
Cartesian components of a vector. Decomposition of a vector into components in the Cartesian coordinate system - analytical approach. Decomposition of a vector into components in the Cartesian coordinate system - geometric approach. Scalar and vector products in the Cartesian coordinate system.
A force as a model of interactions between bodies. Field and contact forces. Discrete and continuous forces. The density of linear, surface and volume continuous forces. Newton's third law of motion. Axiom about the resultant force. Axiom about forces acting on rigid bodies. The moment of a force about a point.
The moment of a force about an axis. Moments of a force about the axes of the Cartesian coordinate system.
A system of forces. Vector sum of forces and vector sum of moments of forces of the system of forces. The relation between sums of moments of a force system with respect to two different points. The parameter of a force system. The couple. The moment of a couple. Equivalent systems of forces. The force-and-couple resultant of a system of forces. Special force systems equivalent to a couple or to a single force. The force resultant.

Axioms of statics. Mechanical equilibrium. Static equilibrium. Equilibrium equations for an arbitrary system of forces. Equilibrium equations for a system of parallel forces. Equilibrium equations for a concurrent system of forces. Equilibrium equations for a coplanar system of forces. Constraints. The axiom about constraints. Supports and their reactions: cable, weightless link, frictionless pin, ball and socket joints, smooth and rough contact, pin supports, fixed support. Equilibrium of interacting bodies. Statically determinate systems.
Basic concepts of kinematics of a point. Kinematic equations of motion in vector form. The motion path of a point. Point displacement, velocity vector, acceleration vector. Description of the motion of a point in Cartesian coordinates. Frenet's coordinate system. The signed arc length coordinate. Description of the motion of a point in Cartesian coordinate. Tangential and normal components of the acceleration vector. Kinematics of a rigid body. Rigid body constraints. Theorem on the projections of the velocity vectors of two rigid body points. Degrees of freedom of a free rigid body. Position of a rigid body with respect to immovable reference frame. Kinematic equations of motion of a free rigid body. Time derivatives of the unit vectors of the moving reference frame. The angular velocity vector and the angular acceleration vector. The velocity and acceleration of any point of the rigid body in general motion. Translational motion of a rigid body. Rotational motion of a rigid body – the kinematic equation of the rotational motion, angular velocity and angular acceleration, accelerated and retarded rotational movement, the velocity and acceleration of any point of the rigid body in the rotational motion, tangential and normal components of the acceleration vector. Plane motion of a rigid body - the kinematic equations of the plane motion, angular velocity and angular acceleration in the plane motion, the velocity and acceleration of any point of the rigid body in the plane motion. Velocity and acceleration vectors at the point of contact of a wheel rolling without slipping with the ground. Instantaneous centre of rotation. Velocity and acceleration analysis for an open kinematic chain. Velocity and acceleration analysis for a closed kinematic chain.
Newton's laws of motion. Inertial frames of reference. Physical independence of forces. Newton's second law of motion for a constrained material particle. Direct and inverse problems of dynamics. Inverse problems of dynamics for a free and constrained material particle. Motion equations and initial conditions. Inverse problems of dynamics – formulation in the Cartesian coordinate system. Formulation of the inverse problems in Frenet's coordinate system. Spherical pendulum. Mathematical pendulum.
Inertia properties of material systems. The density of mass. First moments of inertia of a material system. The centre of mass. First moments of inertia of a material system with respect to the centre of mass. The mass moment of inertia about an axis and radius of gyration. The products of inertia. The Cartesian tensor of inertia. The Cartesian tensor of inertia relative to the centre of mass. The principal axes of inertia. Parallel axis theorem. The rotation matrix. Transformation of a vector and a tensor coordinates when rotating the coordinate system. Invariants of vectors and tensors.
Free and constrained mechanical systems. The momentum of a particle, the momentum of a system of particles, the momentum of a rigid body. The momentum of a material system relative to the mass centre. The angular momentum of a particle, the angular momentum of a system of particles, the angular momentum of a rigid body. The angular momentum of a material system relative to the mass centre. The angular momentum of a rigid body relative to the mass centre. The relation between the angular momentum with respect to any fixed point and with respect to the mass centre. The laws related to change of the momentum and the angular momentum for free and constrained mechanical systems (Euler's motion laws). The kinetic energy of a mechanical system. Koenig's theorem about kinetic energy for a system of particles and for a rigid body. The kinetic energy of a rigid body relative to the mass centre. The work and power of a force. The work-energy theorem for a material particle – differential and integral formulation. The work-energy theorem for a system of particles – differential and integral formulation. The work-energy theorem for a rigid body – differential and integral formulation.

Tutorials: Elements of vector calculus. Algebra of vectors. Dot and cross products of vectors. Decomposition of a vector into Cartesian components.
Statics 2D. Equilibrium of a rigid body and a system of interacting rigid bodies or parts of a structure under a coplanar system of forces. Free body diagrams. Decomposition into subsystems. Equilibrium equations. Static determinacy.
Statics 3D. Equilibrium of a rigid body under an arbitrary spatial system of forces. Free body diagrams. Equilibrium equations.
Inertial properties of bodies. First moments of inertia. Determination of position of the mass centre – analytical approach and the method of composite parts.
Kinematics of a point. Analysis of motion on the basis of the kinematic equations of point in the Cartesian coordinate system. Tangential and normal components of the acceleration vector. The path of the point and its radius of curvature.
Kinematics of the plane motion of chosen mechanisms. Determination of the velocities and the

accelerations of points and the angular velocities and angular accelerations of the mechanism members. Dynamics of a material particle. Formulating and solving inverse problems of dynamics of a material point.

Laboratory classes: Short introduction to Mathematica program with elements of vector calculus. Statics 3D – equilibrium of any spatial force system on the example of a plate supported by six weightless rods. Kinematics of a particle – analysis of the particle motion on the basis of the known kinematic equations in the Cartesian coordinate system. Plane motion of rigid bodies – kinematic analysis of plane mechanisms. Mass distribution and inertia properties of rigid bodies. Moments and products of inertia, tensor of inertia. Steiner's theorem about parallel axes. Rotation matrix. Inertia tensor transformation at rotation of the coordinate system. Solving inverse problems of dynamics of a material particle.

Teaching methods

Lectures: lecture supported by multimedia presentations, solving tasks on the blackboard. Presentations and issues that help students prepare for the exam are available online on the Moodle platform.
Tutorials: problem solving, discussion. A course supporting classes is available on the Moodle platform, containing solutions to tasks with broad comments and proposals for tasks for self learning.
Laboratory classes: solving problems with the use of Mathematica enabling the presentation of results in graphic form and the animation of motion. Discussion of results.

Bibliography

Basic
1. Z. Osiński, Mechanika ogólna, PWN.
2. J. Leyko, Mechanika ogólna t. 1-2, PWN.
3. M. Łunc, A. Szaniawski, Zarys mechaniki ogólnej, PWN.
4. Misiak J., Zadania z mechaniki ogólnej, WNT, Warszawa.
Additional
1. J. R. Taylor, Mechanika klasyczna, t. 1 - 2, PWN.
2. W. Szcześniak, Mechanika klasyczna, analityczna i Mathematica w zadaniach i przykładach obliczeniowych, OWPW, Warszawa.

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	62	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	38	1,50