**KAZAKH-BRITISH TECHNICAL UNIVERSITY**

**Approved by**
**Act.Dean of**
**School of Applied**
**Mathematics**
**__________T.S. Kenzhebayev**
**On 10.07.2025, protocol № 07**

**Syllabus of the Course**
**Theoretical Mechanics, MAT1216**
Semester: Spring of 2025
2023/2024 Academic Year
3 KZ credits (1/0/2)/5 ECTS


**Lecturer and seminar instructors:**
PhD, Assistant Professor, Sinitsa Artem Vitaliyevich.
PhD Candidate, Lecturer of SAM, Yerimbet Meruert Tastanbekkyzy.


| Lecturer/Instructor personal information | Time and place of classes | | Contact information |
|---|---|---|---|
| | Lessons | Office Hours | e-mail |
| Artem V. Sinitsa | according to the schedule, available on wsp.kbtu.kz | *will be announced via M-Teams and* wsp.kbtu.kz | a.sinitsa@kbtu.kz teacher's room # 318, +7-(727)-357-42-42 (ext. 317) |
| Meruyert T. Yerimbet | | | m.yerimbet@kbtu.kz |

**COURSE DURATION:**

- 3 KZ credits\5 ECTS, 15 weeks, 45 class hours;

**COURSE PRE-REQUISITES**:

- It is assumed a sufficient knowledge of advanced mathematics in content of the Calculus-I, II courses as well as understanding of common physics course based on secondary education knowledge.

**COURSE DESCRIPTION**

**Course objectives**

The major elements of the classical mechanics course are the key part of practical implementation of theoretical fundamental knowledge obtained during study on any technical specialty and play the core part in development of the applied engineering skills. Such skills include the ability of interpretation of principal physical laws via mathematical apparatus for further analysis. The essential part of classical mechanics includes the mastering of skill of describing the general motion of solid bodies in space due to various conditions. By implementing the applied mathematical techniques, students will grasp the fundamental knowledge about construction of consistent patterns description for dynamical changes in configuration of multiple-particle systems and their linear, angular and oscillatory motion over line, on plane and in space.

**General Topics**

The general topics of the course construct the following list of studying material:

- Newton laws of motion in differential form and linear vector space;
- Nonuniform circular motion in presence of resistive forces;
- multiple-particle dynamical system configuration and initial and boundary value problems;
- oscillatory, simple harmonic and circular motion in space and mechanical waves;
- center of mass, conservative force fields and potential energy concepts;
- fundamental laws of energy conservation, deformable system, collisions and reactive motion for rocket propulsion.

**Courser learning outcomes**

The general objective of the course is to allow students to master:

- the skills to interpret and analyze data of dynamical system configuration description via mathematical analysis techniques;
- the ability to describe the general motion of the solid bodies in space via fundamental laws of motion;
- the notion of derivation of analytical and numerical solution of initial and boundary value problems by differential and integral theories elements of basic calculus courses;
- understanding of general propositions of analytical mechanics theory in terms of variational principle and virtual work and displacement definitions by grasping essences of Euler-Lagrange integra-differential equation posed for functional mapping optimization.

**Literature**

- *Main Textbooks*

[1]. R. Douglas Gregory, Classical Mechanics, Cambridge University Press, 2006.
[2]. Raymond A. Serway, John W. Jewett, Jr., Physics for Scientists and Engineers, Carnegie Learning, 2012.

- *Supplementary*

[3] Vicente Cortes, Alexander S. Haupt, Mathematical Methods of Classical Physics, Springer, 2017
[4] Alexander L. Fetter, John Dirk Walecka, Nonlinear mechanics a supplement to Theoretical mechanics, Dover Publications, 2006.

## COURSE CALENDAR

| Week № | General Information | | | | SIS and assessments |
|---|---|---|---|---|---|
| | Lessons' content | Lecture classes | Seminar classes | Topics and materials to study | |
| 1 | **Motion in Vector Space**<br><br>The algebra and calculus of vectors. Tangent and normal vectors to a curve. Unit tangent vector. Unit normal vector. Reciprocal basis and vector geometry. Velocity, acceleration, and scalar angular velocity vector valued functions. Straight line motion of a particle: finding rectilinear velocity and acceleration. General motion of a particle. Uniform circular motion. Particle motion in polar coordinates. Polar formulae for velocity and acceleration. General circular motion. Rigid body rotating about a fixed axis. Angular velocity. Rigid body in planar motion. Reference frames in relative motion. | 2 | 1 | **Motion in Vector Space**<br><br>Reading<br><br>[1] § 1.1 – 2.2;<br>[2] § 1.1 – 3.4. | **SIS 1**<br><br>[1] pp. 22-24, # 1.1-1.18, (even problems), p. 44, # 2.3. |
| 2 | **Newtonian Laws of Motion (Part I: Statement)**<br><br>The Concept of Force. Newton's First Law and Inertial Frames. Mass notion. Newton's Second Law. The Gravitational Force and Weight. Newton's Third Law. Analysis Models Using Newton's Second Law. Forces of Friction. The law of multiple and mutual interaction. Center of mass. The Law of Gravitation by distribution of mass and equivalence principle. | 2 | 1 | **Newtonian Laws of Motion (Part I: Statement)**<br><br>Reading<br><br>[1] § 3.1 – 3.8;<br>[2] § 5.1 – 5.8, § 13.1 – 13.6. | **SIS 2:**<br><br>[1] pp. 71-72, # 3.1-3.8 (even problems). |
| 3 | **Newtonian Laws of Motion (Part II: Applications)**<br><br>Extending the Particle in Uniform Circular Motion Model. Nonuniform Circular Motion. Motion in Accelerated Frames. Motion in the Presence of Resistive Forces. Rectilinear motion in a force field. Constrained rectilinear motion. Motion through a resisting medium. Projectiles. | 2 | 1 | **Newtonian Laws of Motion (Part II: Applications)**<br><br>Reading<br><br>[1] § 4.1 – 4.5;<br>[2] § 6.1 – 6.5. | **SIS 3:**<br><br>[1] pp. 98-104, # 4.1-4.36 (even problems). |

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| 4 | **Energy Conservation Principle**<br><br>Systems and Environments. Work Done by a Constant Force. Work Done by a Varying Force. Kinetic Energy and the Work–Kinetic Energy Theorem. Potential Energy of a System. Conservative and Nonconservative Forces. Relationship Between Conservative Forces and Potential Energy. Energy Diagrams and Equilibrium of a System. The energy principle. Energy conservation in rectilinear motion. General features of rectilinear motion. Energy conservation in a conservative field. Energy conservation in constrained motion. Analysis Model: Nonisolated System (Energy). Analysis Model: Isolated System (Energy). Situations Involving Kinetic Friction. Changes in Mechanical Energy for Nonconservative Forces. Power. | 2 | 1 | **Energy Conservation Principle**<br><br>Reading<br><br>[1] § 6.1 – 6.5;<br>[2] § 7.1 – 8.5. | **Quiz - 1**<br><br>**SIS 4:**<br><br>[1] pp. 151-154, # 6.1 – 6.23 (even problems). |
| 5 | **Linear Momentum Conservation Principle**<br><br>Configurations and degrees of freedom. The energy principle for a system. Energy conservation for a system. Kinetic energy of a rigid body. Motion of the center of mass. Conservation of linear momentum. Rocket motion. Collision theory. Collision processes in the zero-momentum frame. The two-body problem. Two-body scattering. Integrable mechanical systems. | 2 | 1 | **Linear Momentum Conservation Principle**<br><br>Reading<br><br>[1] § 10.1 – 10.5;<br>[2] § 9.1 – 9.9. | **SIS 5:**<br><br>[1] pp. 279-281, # 10.1 – 10.12 (even problems). |
| 6 | **Rotational Motion, Rolling and Torque**<br><br>Angular Position, Velocity, and Acceleration. Analysis Model: Rigid Object Under Constant. Angular Acceleration. Angular and Translational Quantities. Torque. Analysis Model: Rigid Object Under a Net Torque. Calculation of Moments of Inertia. Rotational Kinetic Energy. Energy Considerations in Rotational Motion. Rolling Motion of a Rigid Object. Collision processes in the zero-momentum. The two-body problem. Two-body scattering. Integrable mechanical systems. | 2 | 1 | **Rotational Motion, Rolling and Torque**<br><br>Reading<br><br>[1] § 10.6 – 10.10;<br>[2] § 10.1 – 10.9. | **SIS 6:**<br><br>[1] pp. 281-284, # 10.12 – 10.26 (even problems). |
| 7 | **Angular Momentum Conservation Principle**<br><br>The Vector Product and Torque. Analysis Model: Non-isolated System (Angular Momentum). Angular Momentum of a Rotating Rigid Object. Analysis Model: Isolated System (Angular Momentum). The Motion of Gyroscopes and Tops. The moment of a force. Angular momentum. Angular momentum of a rigid. The angular momentum principle. Conservation of angular momentum. Planar rigid body motion. Rigid body statics in three dimensions. | 2 | 1 | **Angular Momentum Conservation Principle**<br><br>Reading<br><br>[1] § 11.1 – 11.7;<br>[2] § 11.1 – 11.5. | **Mid-term**<br><br>**SIS 7:**<br><br>[1] pp. 317-320, # 11.1 – 11.19 (even problems). |

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| 8 | **Static Equilibrium and Elasticity**<br><br>Analysis Model: Rigid Object in Equilibrium. More on the Center of Gravity. Examples of Rigid Objects in Static Equilibrium. Elastic Properties of Solids. Stable equilibrium and small oscillations. | 2 | 1 | **Static Equilibrium and Elasticity**<br><br>Reading<br><br>[1] § 15.1;<br>[2] § 12.1 – 12.4. | **SIS 8:**<br><br>[2] pp. 379-382, # 1 – 30 (even problems). |
| 9 | **Fluid Mechanics**<br><br>Pressure. Variation of Pressure with Depth. Pressure Measurements. Buoyant Forces and Archimedes's Principle. Fluid Dynamics. Bernoulli's Equation. Other Applications of Fluid Dynamics. The phase fluid. | 2 | 1 | **Fluid Mechanics**<br><br>Reading<br><br>[1] p. 408;<br>[2] § 14.1 – 14.7. | **SIS 9:**<br><br>[2] pp. 438-441, # 1 – 40 (even problems). |
| 10 | **Oscillatory Motion**<br><br>Motion of an Object Attached to a Spring. Analysis Model: Particle in Simple Harmonic Motion. Energy of the Simple Harmonic Oscillator. Comparing Simple Harmonic Motion with Uniform. Circular Motion. The Pendulum. Damped Oscillations. Forced Oscillations. Body on a spring. Classical simple harmonic motion. Damped simple harmonic motion. Driven (forced) motion. A simple seismograph. Coupled oscillations and normal modes. | 2 | 1 | **Oscillatory Motion**<br><br>Reading<br><br>[1] § 5.1 – 5.6;<br>[2] § 15.1 – 15.7. | **Quiz - 2**<br><br>**SIS 10:**<br><br>[1] pp. 126 - 130, # 5.1 – 5.18 (even problems). |
| 11 | **Wave Motion**<br><br>Propagation of a Disturbance. Analysis Model: Traveling Wave. The Speed of Waves on Strings. Reflection and Transmission. Rate of Energy Transfer by Sinusoidal Waves on Strings. The Linear Wave Equation. Pressure Variations in Sound Waves. Speed of Sound Waves. Intensity of Periodic Sound Waves. The Doppler Effect. | 2 | 1 | **Wave Motion**<br><br>Reading<br><br>[2] § 16.1 – 16.6. § 17.1 – 17.4. | **SIS 11:**<br><br>[1] pp. 525-527, # 1 – 30 (even problems).<br><br>[2] pp. 501-503, # 1 – 31 (even problems). |
| 12 | **Lagrange's equations and conservation principles. Part-1.**<br><br>Constraints and constraint forces. Generalized coordinates. Configuration space (q–space). D'Alembert's principle. Lagrange's equations. Systems with moving constraints. The Lagrangian. The energy functions. Generalized momenta. Symmetry and conservation principles. | 2 | 1 | **Lagrange's equations and conservation principles**<br><br>Reading<br><br>[1] § 12.1 – 12.10. | **SIS 13:**<br><br>[1] pp. 361 – 365 # 12.1 – 12.22 (even problems). |

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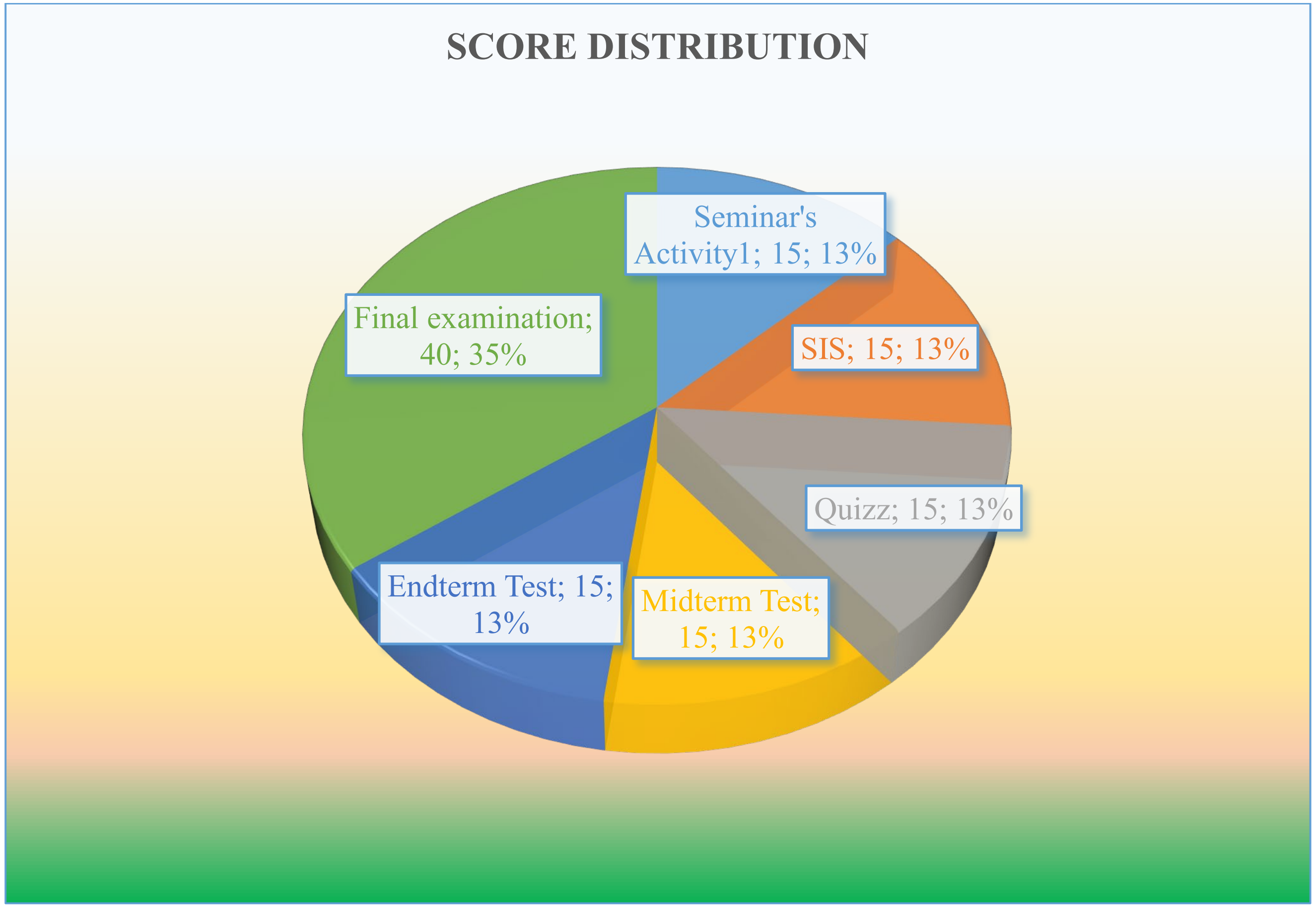
| 13 | **Lagrange's equations and conservation principles. Part-2.**<br><br>Constraints and constraint forces. Generalized coordinates. Configuration space (q–space). D'Alembert's principle. Lagrange's equations. Systems with moving constraints. The Lagrangian. The energy functions. Generalized momenta. Symmetry and conservation principles. | 2 | 1 | **Lagrange's equations and conservation principles**<br><br>Reading<br><br>[1] § 12.1 – 12.10. | **SIS 13:**<br><br>[1] pp. 361 – 365 # 12.1 – 12.22 (even problems). |
| 14 | **The calculus of variations and Hamilton's principle**<br><br>Some typical minimization problems. The Euler–Lagrange equation. Variational principles. Hamilton's principle. | 2 | 1 | **The calculus of variations and Hamilton's principle**<br><br>Reading<br><br>[1] § 13.1 – 13.4. | **End-term**<br><br>**SIS 14:**<br><br>[1] pp. 388-391, # 13.1 – 13.14 (even problems). |
| 15 | **Hamilton's equations and phase space**<br><br>Systems of first order ODEs. Legendre transforms. Hamilton's equations. Hamiltonian phase space ((q, p)–space). Liouville's theorem and recurrence. | 2 | 1 | **Hamilton's equations and phase space**<br><br>Reading<br><br>[1] § 14.1 – 14.5; | **SIS 15:**<br><br>[1] pp. 413-418, # 14.1 – 14.16 (even problems). |

**COURSE ASSESSMENT PARAMETERS**

*Score distribution according to each category percentile*



*Tentative timetable of exams and tasks:*

| № | Assessment Criteria | Week № | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | - |
| 1 | Seminar's Activity[1] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 15 |
| 2 | SIS[2] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 15 |
| 3 | Quiz | * | * | * | 7,5 | * | * | * | * | * | 7,5 | * | * | * | * | * | 15 |
| 4 | Mid-term Test | * | * | * | * | * | * | 15 | * | * | * | * | * | * | * | * | 15 |
| 5 | End-term Test | * | * | * | * | * | * | * | * | * | * | * | * | * | 15 | * | 15 |
| 6 | Final examination | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 40 |
| 7 | Total | 2 | 2 | 2 | 9,5 | 2 | 2 | 17 | 2 | 2 | 9,5 | 2 | 2 | 2 | 17 | 2 | 115[3] |

[1] *Bonus points – Seminar activity points are assigned for solved problems of higher difficulty level during the seminar class on the whiteboard.*
[2] *Student Individual Studies (SIS) – weekly distributed homework for compulsory completion.*
[3] *Assume 15 points as bonus points (additional)*

**Lectures** are conducted in the form of explaining the theory given in the course that is why students supplied with handouts uploaded into the intranet. Activity and attendance on lessons is mandatory. Mandatory requirement is preparation for each lesson. Lectures are conducted through online platform.

**Grading policy:**

Intermediate attestations (on 7$^{th}$ and 14$^{th}$ week) join topics of all lectures, homework, quiz and materials for reading discussed to the time of attestation. Maximum number of points within attendance, activity, homework, quiz, and laboratories for each attestation is 30 points.

Final exam joins and generalizes all course materials, is conducted in the complex form with questions and problems. Final exam duration is usually 120 min. Maximum number of points is 40. At the end of the semester, students receive overall total grade (summarized index of students' work during semester) according to conventional KBTU grade scale.

**ACADEMIC POLICY**

**Students are required:**

- to be respectful to the teacher and other students;
- to switch off mobile phones during classes;
- DO NOT cheat. Plagiarized papers shall be graded with zero points!
- to come to classes prepared and actively participate in classroom work; to meet the deadlines;
- to enter the room before the teacher starts the lesson;
- to attend all classes. No make-up tests or quiz are allowed unless there is a valid reason for missing it (verified by documents);
- If student miss more than 30% of classes – there is no access to the Final Examination, even if the student has medical verification.
- to follow KBTU academic policy regarding **W, AW, I, F** grades.
- When students have a score of 29 or less for attestation 1 added to attestation 2, then their grade is F.
- When students have a score of 19 or less (less than 50%) for their final exam, then their grade is F.
- When students do not come for their final exam, then their grade is F.
- All rules of the current Academic Policy of KBTU should be followed by students.

**Students are encouraged to**

- consult the teacher on any issues related to the course.
- make up within a week's time for the works undone for a valid reason without any grade deductions.

*PhD, Assistant Professor, Artem V. Sinitsa* ________
*PhD Candidate, MSc, Lecturer, Meruert T. Yerimbet* ________