Ministry of Education and Science of Ukraine

National Aerospace University
"Kharkiv Aviation Institute"

Department 202 «Theoretical Mechanics, Engineering and Robotic Systems»

APPROVED

Acting Head of Scientific
Methodical Committee

M.S. Romanov

«30» August 2021

WORKING PROGRAM OF COMPULSORY ACADEMIC DISCIPLINE

"Engineering Mechanics (Theoretical Mechanics and Theory of Mechanisms and Machines)"/ТЕОРЕТИЧНА МЕХАНІКА ТА ТЕОРІЯ МЕХАНІЗМІВ І МАШИН (іноземною мовою)
(name of academic discipline)

Fields of study: 13 «Mechanical Engineering»,
27 «Transport Services»
Specialities: 134 «Aviation and Aerospace Technologies»,
272 «Aviation Transport»

Educational programs: «Airplanes and helicopters»,
«Design and production of constructions from composite materials»,
«Production technologies of aircrafts»,
«Aircraft engines and power plants»,
«Satellites, engines and power plants»
«Maintenance service and repair of aircrafts and aircraft engines»
«Супутники, двигуни та енергетичні установки. Інженерно технічний переклад)»

Full-time tuition
Level of higher education: bachelor's (first cycle)

Kharkiv 2021

Working program of academic discipline "Engineering Mechanics (Theoretical Mechanics and Theory of Mechanisms and Machines)"/ТЕОРЕТИЧНА МЕХАНІКА ТА ТЕОРІЯ МЕХАНІЗМІВ І МАШИН (іноземною мовою)" is for students of program subject areas 134 «Aviation and Aerospace Technologies» and 272 «Aviation Transport»

Educational programs: «Airplanes and helicopters»

«Design and production of constructions from composite materials»,
«Production technologies of aircrafts»,
«Aircraft engines and power plants»,
«Satellites, engines and power plants»
«Maintenance service and repair of aircrafts and aircraft engines»
«Супутники, двигуни та енергетичні установки. Інженерно технічний переклад)»

June 25, 2021 - 18 p.

Developers:

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Working program was approved at the meeting of Department 202 «Theoretical Mechanics, Engineering and Robotic Systems»
Minutes #11 – June 30, 2021

Head of Department, DSc, Professor_____ O.O. Baranov

1. Description of the discipline

<table>
<tr><td rowspan="2">Characteristics</td><td rowspan="2">Branch of science, specialization, academic degree</td><td colspan="2">Description of the discipline</td></tr>
<tr><td colspan="2">full-time tuition</td></tr>
<tr><td>Credits –10</td><td rowspan="3">Fields of study:
13 «Mechanical Engineering»,
27 «Transport Services»</td><td colspan="2">Compulsory</td></tr>
<tr><td>Module – 4</td><td colspan="2" rowspan="2">Academic year:</td></tr>
<tr><td>Thematic modules – 4</td></tr>
<tr><td rowspan="3">Individual tasks:
«System of two rigid bodies equilibrium (2D)»
«Work-Energy principle for system of bodies motion analysis»</td><td rowspan="3">Specialties:
134 «Aviation and Aerospace Technologies»,
272 «Aviation Transport»</td><td colspan="2">2021/ 2022</td></tr>
<tr><td colspan="2">Semester</td></tr>
<tr><td>2nd</td><td>3rd</td></tr>
<tr><td rowspan="2">Total number of academic hours – 160/300</td><td rowspan="3"></td><td colspan="2">Lectures, a.h.</td></tr>
<tr><td>32</td><td>32</td></tr>
<tr><td rowspan="6">Number of weekly academic hours for full-time tuition:
auditorium – 5
independent work – 4,375</td><td colspan="2">Practices, seminars, a.h.</td></tr>
<tr><td rowspan="3">Level of higher education:
bachelor’s (first cycle)</td><td>48</td><td>40</td></tr>
<tr><td colspan="2">Laboratory activities, a.h.</td></tr>
<tr><td colspan="2">-</td></tr>
<tr><td rowspan="4"></td><td colspan="2">Independent work, a.h.</td></tr>
<tr><td>70</td><td>78</td></tr>
<tr><td colspan="2">Form of examination</td></tr>
<tr><td colspan="2">examination</td></tr>
</table>

Note: ratio between classroom hours and student independent work hours for full-time education is equal: 152/148=1,03

2. The objective and outcomes of the course

Purpose of the study: to master the laws of classical mechanics and methods of analytical study of the mechanical motion (as well as the rest) of the material point, solid body and mechanical system.

The **objective** of the course is learning of the basic concepts and laws of statics, kinematics and dynamics for use in the calculations of motion and equilibrium of mechanical systems; learning of methods of kinematic and dynamic analysis and synthesis of mechanisms to gain experience and practical skills in solving problems related to research mechanisms and components of aviation equipment.

The **task** of the course is to provide students with the knowledge and skills to design and research the mechanisms and machines and to explore the topics of kinematics and dynamics of

machinery in respect to the synthesis of mechanisms in order to accomplish desired motions or tasks, and also the analysis of mechanisms in order to determine their dynamic behavior.

According to the requirements of the educational-professional program, students must achieve such **competencies**:

Ability to communicate in a foreign language.

Ability to generate new ideas (creativity).

Ability to make informed decisions.

Ability to learn and master modern knowledge.

Ability to use theories of flight dynamics and control in the design of rocket and space technology.

Ability to design and test elements of rocket and space technology, its equipment, systems and subsystems.

Program learning outcomes:

Fluent in oral and written foreign language on professional matters.

Have the skills of self-study and autonomous work to improve professional skills and solve problems in a new or unfamiliar environment.

Have the skills to determine the loads on the structural elements of rocket and space technology at all stages of its life cycle.

Apply modern methods of design, construction and production of elements and systems of rocket and space technology in professional activities.

Understand and justify the design features and basic aspects of work processes in systems and elements of rocket and space technology.

Previous courses: Physics, Higher Mathematics.

Accompanying courses: Theoretical Mechanics and Theory of Mechanisms and Machines (CP), Machine Elements, Mechanics of Materials and Structures.

3. Course Content

TERM 2

Thematic module 1. Statics, Analysis of Lever Mechanisms

1. Introduction. Two principal problems of statics. Main conception of statics: rigid body, force, system of forces, resultant of a force system, balanced force system. Axioms of statics. Main conceptions of vector algebra used in statics. Classification of forces: internal and external forces, concentrated and distributed forces, applied forces and reactions. Constraints and their reactions. Procedure of forming of free body diagram.
2. The resultant of concurrent force system. Methods of resultant determination: analytical, graphical. Equilibrium equation of concurrent force system. Vector and axial moment of force. Couples of forces and their features. Couple theorems.
3. General force system. Translation of a force to a parallel position. Total vector and total moment about a center of a general force system. Main theorem of statics (theorem about general force system reduction). Total moment dependence on a position of a reduction center. General force system equations of equilibrium. Special force system equations of equilibrium. Procedure of solving of problem about single constrained body equilibrium. System of bodies. Problem about system of constrained bodies equilibrium, procedure of solving.
4. Classification of forces: internal and external forces, concentrated and distributed forces, applied forces and reactions. Constraints and their reactions. Procedure of forming of free body diagram (FBD). Procedure of solving of problem about single constrained body equilibrium. System of bodies. Problem about system of constrained bodies equilibrium, procedure of solving.

5. Parallel force system resultant. Varignon's theorem. Mass centre of a rigid body, system of bodies. Methods of mass enter position determination.

Thematic module 2. Kinematics, Analysis of Gear Mechanisms

6. Space and time in classical mechanics. Reference systems. Main problems of kinematics of a particle. Different methods of a particle motion representation: vector, coordinate and in terms of path (natural). Velocity and acceleration: vector and coordinate methods. Velocity and acceleration in terms of path variables. Normal and tangential accelerations. Cases when normal and tangential accelerations equal zero. Analytical researching of motion and researching with help of velocity hodograph.
7. Main problems of a rigid body kinematics. Translation of a rigid body, features of the motion. Rotation of a rigid body about fixed axis, the motion description. Angular velocity and angular acceleration of body. Velocity and acceleration of a point of rotating body.
8. Plane motion of rigid body. Equations of motion. Chasles' theorem. Velocity of a body's point. Instantaneous center of zero velocity (ICV). Methods of ICV finding. ICV as pole. Plane motion of rigid body. Acceleration of point on a body.
9. Spherical motion of a rigid body (rotation about a fixed point). Instantaneous axis of rotation. Angular velocity and angular acceleration of the body. Velocity of a point on the body. Acceleration of a point on the body. Motion of a free body. Velocity and acceleration of a free body point.
10. Relative motion of a particle. General relationship between time derivatives of a vector for different references, the relationship between velocities of a particle for different references, acceleration of a particle for different references. Cases when Coriolis acceleration equals zero.
11. Structural analysis of mechanisms. Links and kinematic pairs. Kinematic chains. The structural formulas of spatial and planar mechanisms. Mobility of mechanisms.
12. Kinematic analysis of mechanisms. Kinematic analysis of lever mechanisms by graph-analytical method. Construction of velocity and acceleration diagrams for four-bar linkages of the second class. Kinematic analysis of slotted link mechanism by means of graph-analytical method
13. Kinematic analysis of gear trains. Analytical method of gearings analysis. Gear ratio of simple gear trains. Linear and angular velocity diagrams of gearings.
14. Kinematic analysis of planetary and differential gear trains. Kinematic analysis by analytical method. Graphical method of epicyclic gearing analysis: construction of linear and angular velocity diagrams.

TERM 3

Thematic module 3. Dynamics and Base of Analytical Mechanics.

Topics

1. Dynamics of a Particle. Axioms of dynamics. The two main problems of dynamics. Solution of direct and inverse problems of particle dynamics.
2. Motion of a particle with respect to the noninertial frame of reference. Free and constrained particles equations of motion in noninertial frame of reference. Forces of inertia their features. Classical mechanics relativity principle. The relative resting conditions.
3. Linear momentum of a particle. Total linear momentum of the particle system. Force-momentum principle. Principle of linear momentum conservation. Principle of system mass-center motion. Differential equations of translational motion of particles system.
4. Angular momentum of a particle. Total angular momentum of the particle system about fixed point and about fixed coordinate axes. Angular momentum principle for a system of particles in inertial frame of reference. Principle of angular momentum conservation. Total angular momentum about a fixed center for compound motion of the particle system Angular momentum principle for a system of particles with respect to Kenig's frame of reference. Angular momentum

of a rigid body rotating about a fixed axis. Mass moment of inertia about an axis (axial), about a pole (polar), Parallel-axes theorem. The simplest bodies axial moments. Differential equation of motion for a rigid body rotating about a fixed axis (Second Newton's law for rotation)

5. Differential equation of a rigid body plane motion. Statics and kinetics friction. Methods of problems solution: rolling without slipping, rolling with slipping.

6. Particle kinetic energy. Kinetic energy of a particle system. Kenig's theorem. Rigid body kinetic energy for translation, rotation, plane and spherical motion. Elementary and total work done by a force. Force power. Methods of determination of elementary and total work done by a force if force is constant, force is linear function of displacement. Principle of work and kinetic energy for a particle system in differential and integral form. Conservative force fields. Mathematical criterion of force field conservatism. Law of conservation of mechanical energy for conservative systems.

7. Motion modes of mechanisms. Dynamic equations of speeding-up, steady-state motion and running-out. Mechanical efficiency. Efficiency of mechanisms connected in series and parallel. Dynamic analysis of mechanisms. Mechanism dynamic model. Reduction of forces and moments of forces. Reduction of mass and moments of inertia. The equations of dynamic model motion. Irregularity factor of motion.

8. Characteristics of non-uniformity of motion at steady motion. Research of the established modes of movement of mechanisms. Determination of the moment of inertia of the flywheel according to the energy-mass diagram.

9. Dalambert's principle. Kinetostatics method. Total vector and total moment of inertia forces for a particle system and for a rigid body. Force analysis of mechanisms. The forces acting on the mechanism and their characteristics. Determination of dynamical reactions in kinematic pairs and balancing force (balancing moment) by Bruevich's method.

10. Base notion of analytical mechanics. Constraints and their classification. Particle displacement (actual, virtual, possible) Generalized coordinates. Generalized forces. Ideal constraints.

11. General equation of dynamics. Procedure of application of GED for problem solution. Virtual work principle (VWP). Application of VWP for reactive forces determination.

Thematic module 4. Synthesis of mechanisms.

Topics.

12. Synthesis of gearings. The main theorem of gearing and its consequence. Involute of a circle, its properties and equations. Involute meshing of cylindrical gears. Rack and pinion meshing.

13. Gear cutting. Generating process and form-copying method.Pitch circle, teeth module. Counter profile, standard basic rack tooth profile.

14. Types of gears, which formed by the rack. Addendum modification. Zero, positive and negative gears. Teeth undercut. Addendum modification limit for external gears dependent on the virtual number of teeth.

15. Determination of geometrical parameters of involute gears. Positive, negative and zero gearing. Base circle, working pitch circle, root circle, tip circle, tooth thickness on the pitch circle, tooth thickness on the arc of a circle of arbitrary radius, center distance, pressure angle. Qualitative indicators of involute gearing: transverse contact ratio, specific sliding, geometric coefficient of specific pressure. Selection of addendum modification coefficient. Blocking contours.

16. Synthesis of gear trains and lever mechanisms. Synthesis of planetary and differential gear trains. Selection condition of planetary gearings schemes and number of gear teeth. Synthesis of lever mechanisms. The conditions of crank existence in planar mechanisms. Synthesis of mechanisms by a variation factor of output link average speed, by pressure angle and by angle of force transmission.

4. Course arrangement

Names of Modules and Topics	Number of hours				
	total				
	total	namely			
		lec	pr	lab	i.w.
1	2	3	4	5	7
Term 2					
Module 1					
Thematic module 1					
TOPIC 1. Introduction. Two principal problems of statics. Main conception of statics: rigid body, force, system of forces, resultant of a force system, balanced force system. Axioms of statics. Main conceptions of vector algebra used in statics.	6	2	2		2
TOPIC 2. The resultant of concurrent force system. Methods of resultant determination: analytical, graphical. Equilibrium equation of concurrent force system. Vector and axial moment of force. Couples of forces and their features. Couple theorems.	8	2	4		2
TOPIC 3. General force system. Translation of a force to a parallel position. Total vector and total moment about a center of a general force system. Main theorem of statics (theorem about general force system reduction). Total moment dependence on a position of a reduction center. General force system equations of equilibrium. Special force system equations of equilibrium.	10	2	4		4
TOPIC 4. Classification of forces: internal and external forces, concentrated and distributed forces, applied forces and reactions. Constraints and their reactions. Procedure of forming of free body diagram (FBD). Procedure of solving of problem about single constrained body equilibrium. System of bodies. Problem about system of constrained bodies equilibrium, procedure of solving.	14	2	6		6
TOPIC 5. Parallel force system resultant. Varignon's theorem. Mass centre of a rigid body, system of bodies. Methods of mass enter position determination	4	2	-		2
Module work 1	2		2		
Totally for Thematic module 1	44	10	18	0	16
Thematic module 2					
TOPIC 6. Particle kinematics. Space and time in classical mechanics. Reference systems. Main problems of kinematics of a particle. Different methods of a particle motion representation: vector, coordinate and in terms of path (natural). Velocity and acceleration: vector and coordinate methods. Velocity and acceleration in terms of path variables. Normal and tangential accelerations. Cases when normal and tangential accelerations equal zero. Analytical researching of motion and researching with help of velocity hodograph.	6	2	2		2
TOPIC 7. Main problems of a rigid body kinematics. Translation of a rigid body, features of the motion. Rotation of a rigid body about fixed axis, the motion description. Angular velocity and angular acceleration of body. Velocity and acceleration of a point of rotating body.	8	2	4		2
TOPIC 8. Plane motion of rigid body. Equations of motion. Chasles' theorem. Velocity of a body's point. Instantaneous center of zero velocity (ICV). Methods of ICV finding. ICV as pole. Plane motion of rigid body. Acceleration of point on a body.	16	2	6		8
TOPIC 9. Spherical motion of a rigid body (rotation about a fixed point). Instantaneous axis of rotation. Angular velocity and angular acceleration of the body. Velocity of a point on the body. Acceleration	4	2	-		2

of a point on the body. Motion of a free body. Velocity and acceleration of a free body point.					
TOPIC 10. Compound motion of a particle. General relationship between time derivatives of a vector for different references, the relationship between velocities of a particle for different references, acceleration of a particle for different references. Cases when Coriolis acceleration equals zero. Compound motion of a body.	14	4	4		6
TOPIC 11. Structural analysis of mechanisms. Links and kinematic pairs. Kinematic chains. The structural formulas of spatial and planar mechanisms. Mobility of mechanisms.	6	2	2		2
TOPIC 12. Kinematic analysis of mechanisms. Kinematic analysis of lever mechanisms by graph-analytical method. Construction of velocity and acceleration diagrams for four-bar linkages of the second class. Kinematic analysis of slotted link mechanism by means of graph-analytical method	12	4	4		4
TOPIC 13. Kinematic analysis of gear trains. Analytical method of gearings analysis. Gear ratio of simple gear trains. Linear and angular velocity diagrams of gearings.	6	2	2		2
TOPIC 14. Kinematic analysis of planetary and differential gear trains. Kinematic analysis by analytical method. Graphical method of epicyclic gearing analysis: construction of linear and angular velocity diagrams.	8	2	4		2
Module work 2	2		2		
Totally for thematic module 2	82	22	30	0	30
Module 2					
Individual task 1	24				24
Totally for term	150	32	48	0	70
TERM 3					
Thematic module 3					
TOPIC 1. Dynamics of a Particle. Axioms of dynamics. The two main problems of dynamics. Solution of direct and inverse problems of particle dynamics.	6	2	2		2
TOPIC 2. Motion of a particle with respect to the noninertial frame of reference. Free and constrained particles equations of motion in noninertial frame of reference. Forces of inertia their features. Classical mechanics relativity principle. The relative resting conditions.	8	2	2		4
TOPIC 3. Linear momentum of a particle. Total linear momentum of the particle system. Force-momentum principle. Principle of linear momentum conservation. Principle of system mass-center motion. Differential equations of translational motion of particles system.	6	2	2		2
TOPIC 4. Angular momentum of a particle. Total angular momentum of the particle system about fixed point and about fixed coordinate axes. Angular momentum principle for a system of particles in inertial frame of reference. Principle of angular momentum conservation. Angular momentum of a rigid body rotating about a fixed axis. Differential equation of motion for a rigid body rotating about a fixed axis (Second Newton's law for rotation). Total angular momentum about a fixed center for compound motion of the particle system Angular momentum principle for a system of particles with respect to Kenig's frame of reference.	10	2	4		4
TOPIC 5. Differential equation of a rigid body plane motion.	6	2	2		2

Statics and kinetics friction. Methods of problems solution: rolling without slipping, rolling with slipping.					
TOPIC 6. Particle kinetic energy. Kinetic energy of a particle system. Kenig's theorem. Rigid body kinetic energy for translation, rotation, plane and spherical motion. Elementary and total work done by a force. Force power. Methods of determination of elementary and total work done by a force if force is constant, force is linear function of displacement. Principle of work and kinetic energy for a particle system in differential and integral form. Conservative force fields. Mathematical criterion of force field conservatism. Law of conservation of mechanical energy for conservative systems	8	2	2		4
17. TOPIC 7. Motion modes of mechanisms. Dynamic equations of speeding-up, steady-state motion and running-out. Mechanical efficiency. Efficiency of mechanisms connected in series and parallel. Dynamic analysis of mechanisms.	8	2	2		4
TOPIC 8. Characteristics of non-uniformity of motion at steady motion. Research of the established modes of movement of mechanisms. Determination of the moment of inertia of the flywheel according to the energy-mass diagram.	8	2	2		4
TOPIC 9. Dalambert's principle. Kinetostatics method. Total vector and total moment of inertia forces for a particle system and for a rigid body. Force analysis of mechanisms. The forces acting on the mechanism and their characteristics. Determination of dynamical reactions in kinematic pairs and balancing force (balancing moment) by Bruevich's method.	10	2	4		4
TOPIC 10. Base notion of analytical mechanics. Constraints and their classification. Particle displacement (actual, virtual, possible) Generalized coordinates. Generalized forces. Ideal constraints.	8	2	2		4
TOPIC 11. General equation of dynamics. Procedure of application of GED for problem solution. Virtual work principle (VWP). Application of VWP for reactive forces determination.	8	2	2		4
Module work 3	2		2		
Totally for thematic module 3	88	22	28	0	54
Thematic module 4					
TOPIC 12. Synthesis of gearings. The main theorem of gearing and its consequence. Involute of a circle, its properties and equations. Involute meshing of cylindrical gears. Rack and pinion meshing.	12	2	-		2
TOPIC 13 Gear cutting. Generating process and form-copying method. Pitch circle, teeth module. Counter profile, standard basic rack tooth profile.	6	2	2		2
TOPIC 14. Types of gears, which formed by the rack. Addendum modification. Zero, positive and negative gears. Teeth undercutting. Addendum modification limit for external gears dependent on the number of teeth.	12	2	2		4
TOPIC 15. Determination of geometrical parameters of involute gears. Positive, negative and zero gearing. Base circle, working pitch circle, root circle, tip circle, tooth thickness on the pitch circle, tooth thickness on the arc of a circle of arbitrary radius, center distance, pressure angle. Qualitative indicators of involute gearing: transverse contact ratio, specific sliding, geometric	6	2	2		4

coefficient of specific pressure. Selection of addendum modification coefficient. Blocking contours.					
TOPIC 15. Synthesis of gear trains and lever mechanisms. Synthesis of planetary and differential gear trains. Selection condition of planetary gearings schemes and number of gear teeth. Synthesis of lever mechanisms. The conditions of crank existence in planar mechanisms. Synthesis of mechanisms by a variation factor of output link average speed, by pressure angle and by angle of force transmission.	10	2	4		4
Module work 4	2		2		
Totally for thematic module 4	38	10	12	0	16
Totally for Module 3	126	32	40	0	54
Module 4					
Individual task 1	24				24
Exam					
Totally for term	150	32	40	0	78
Totally for the subject	300	64	88		148

5. Practices

№	Name	Hours
	Term 2	
	Topics 1 and 2. Force. Force resolution onto components, composition of forces. Algebraic moment of force about a center	6
2.	Topic 4. Equilibrium of a body (2D). Reaction of constraints. FBD	2
3.	Topic 4. Equilibrium of a system of bodies (2D).	2
4.	Topic 3. General force system. Total vector and total moment about choosing center of reduction	6
5.	Module 1	2
6.	Topic 6. Particle kinematics	2
7.	Topic 7. Rigid body in translation. Rigid body rotation about fixed axis	4
8.	Topic 8. Plane motion of a rigid body	6
9.	Topic 10. Particle compound motion	4
10.	Topic 11. Structural analysis of mechanisms. Mobility of mechanisms.	2
11.	Topic 12. Kinematic analysis of four-bar linkage and slotted link mechanism by means of graph-analytical method	4
12.	Topic 13. Kinematic analysis of simple gear trains	2
13.	Topic 14. Kinematic analysis of planetary and differential gear trains	4
14.	Module 2	2
	Total	48
	Term 3	
1.	Topic 1. Particle dynamics in inertial frame of reference .	2
2.	Topic 2. Particle dynamics in noninertial frame of reference .	2
3.	Topic 3. Force-linear momentum principle	2
4.	Topic 4. Moment-angular momentum principle in inertial frame of reference. Differential equation of rigid body rotation. Moment-angular momentum principle in noninertial frame of reference.	4
5.	Topic 5. Differential equations of plane motion of rigid body.	2
6.	Topic 6.7,8 Work-energy principle. Mechanical energy conservation.	6
7.	Topic *9.* Dalambert's principle. Kinetostatics method. Total vector and total moment of inertia forces for a particle system and for a rigid body.	4

8.	Topic *10,11.* General equation of dynamics. Procedure of application of GED for problem solution. Virtual work principle (vwp). Application of vwp for reactive forces determination.	4
9.	**Module quiz 3**	2
10.	**TOPIC 13** Gear cutting. Generating process and form-copying method. Pitch circle, teeth module. Counter profile, standard basic rack tooth profile.	2
11.	**TOPIC 14.**. Addendum modification. Zero, positive and negative gears. Teeth undercut. Addendum modification limit for external gears dependent on the virtual number of teeth.	2
12.	**TOPIC 15.** Determination of geometrical parameters of involute gears. Positive, negative and zero gearing. Qualitative indicators of involute gearing.	2
13.	**TOPIC 15.** Synthesis of gear trains and lever mechanisms. Synthesis of planetary and differential gear trains.	4
14.	**Module quiz 4**	2
	Total	40

6. Independent work

№	Name	Hours
	Term 2	
1.	**TOPIC 1.** Two main problems of statics Axioms of statics.	2
2.	**TOPIC 2.** The resultant of concurrent force system. Equilibrium equation of concurrent force system. Vector and axial moment of force. Couples.	2
3.	**TOPIC 3.** General force system. Total vector and total moment about a center of a general force system. Main theorem of statics. General force system equations of equilibrium. Special force system equations of equilibrium.	4
4.	**TOPIC 4.** Classification of forces: Constraints and their reactions. FBD. Main conceptions of vector algebra used in statics. Method of section.	6
5.	**TOPIC 5.** Parallel force system resultant. Varignon's theorem. Mass centre of a rigid body, system of bodies. Methods of mass enter position determination	2
6.	**TOPIC 6.** Particle kinematics.	2
7.	**TOPIC 7.** Translation of a rigid body features of the motion. Rotation of a rigid body about fixed axis.	2
8.	**TOPIC 8.** Plane motion of rigid body.	8
9.	**TOPIC 9.** Spherical motion of rigid body.	2
10.	**TOPIC 10.** Particle compound motion**.**	6
11.	**TOPIC 11.** Structural analysis of mechanisms. Links and kinematic pairs. Kinematic chains. The structural formulas of spatial and planar mechanisms. Mobility of mechanisms.	2
12.	**TOPIC 12.** Kinematic analysis of mechanisms. Kinematic analysis of lever mechanisms by graph-analytical method. Construction of velocity and acceleration diagrams for four-bar linkages of the second class. Kinematic analysis of slotted link mechanism by means of graph-analytical method	4
13.	**TOPIC 13.** Kinematic analysis of gear trains. Analytical method of gearings analysis. Gear ratio of simple gear trains. Linear and angular velocity diagrams of gearings.	2
14.	**TOPIC 14.** Kinematic analysis of planetary and differential gear trains. Kinematic analysis by analytical method. Graphical method of epicyclic gearing analysis: construction of linear and angular velocity diagrams.	2
15.	**Individual task**	24

16.	**Total**	70
	Term 3	
1.	**TOPIC 1.** Axioms of dynamics Particle dynamics in inertial frame of reference .	2
2.	**TOPIC 2.** Particle dynamics in noninertial frame of reference .	4
3.	**TOPIC 3.** Force-Linear momentum principle	2
4.	**TOPIC 4.** Moment-Angular momentum principle in inertial frame of reference. Differential equation of rigid body rotation. Moment-Angular momentum principle in noninertial frame of reference.	4
5.	**TOPIC 5.** Differential equations of plane motion of rigid body.	2
6.	**TOPIC 6.** Work-Energy principle. Mechanical energy conservation.	4
7.	**TOPIC 7.** Motion modes of mechanisms. Dynamic equations of speeding-up, steady-state motion and running-out. Mechanical efficiency. Efficiency of mechanisms connected in series and parallel. Dynamic analysis of mechanisms.	4
8.	**TOPIC 8.** Characteristics of non-uniformity of motion at steady motion. Research of the established modes of movement of mechanisms. Determination of the moment of inertia of the flywheel according to the energy-mass diagram.	4
9.	**TOPIC *9.*** Dalambert's principle. Kinetostatics method. Total vector and total moment of inertia forces for a particle system and for a rigid body.	4
10.	**TOPIC *10.*** Base notion of analytical mechanics. Constraints and their classification. Particle displacement (actual, virtual, possible) Generalized coordinates. Generalized forces. Ideal constraints.	4
11.	**TOPIC *11.*** General equation of dynamics. Procedure of application of GED for problem solution. Virtual work principle (VWP). Application of VWP for reactive forces determination. Conservative mechanical system stability.	4
12.	**TOPIC 12.** Synthesis of gearings. The main theorem of gearing and its consequence. Involute of a circle, its properties and equations. Involute meshing of cylindrical gears. Rack and pinion meshing.	2
13.	**TOPIC 13** Gear cutting. Generating process and form-copying method. Pitch circle, teeth module. Counter profile, standard basic rack tooth profile.	2
14.	**TOPIC 14.**. Addendum modification. Zero, positive and negative gears. Teeth undercut. Addendum modification limit for external gears dependent on the virtual number of teeth.	4
15.	**TOPIC 15.** Determination of geometrical parameters of involute gears. Positive, negative and zero gearing. Qualitative indicators of involute gearing.	4
16.	**TOPIC 16.** Synthesis of gear trains and lever mechanisms. Synthesis of planetary and differential gear trains.	4
17.	**Individual task**	24
	Total	78

7. Individual tasks

№	Name	Hours
1	Calculation-graphic work 1 «System of two rigid bodies equilibrium (2D)». Stages of work. System of two rigid bodies equilibrium (2D) – FBD for system of two rigid bodies forming; – FBD for separated bodies forming; – Forming of Equilibrium conditions for separated bodies;	24

	– Solution of system of linear algebraic equations (equilibrium conditions equations); – Checking up of the solution with help of Equilibrium conditions for system of two rigid bodies; Results analysis. «Plane motion of Rigid body. Particle compound motion». Stages of work. Plane motion of Rigid body – Bodies character of motion analysis; – Position of ICZV determination; – Determination of Angular velocity of rigid body in plane motion; – Determination of velocities of points of rigid body in plane motion; – Choice of the method of determination of angular acceleration of rigid body in plane motion; – Solution of vector equations about linear accelerations distribution for bodies in the problem. – Position of ICZA determination, Checking up of the problem solution. Compound motion of a particle – Determination of character of bulk motion, type of relative motion of the particle; – Determination of relative, bulk and absolute velocities, Graphical presentation of the velocities; – Determination of relative, bulk, Coriolis' and absolute accelerations, Graphical presentation of the accelerations.	
2	Calculation-graphic work 2 "Work-Energy principle for system of bodies motion analysis." – Choice of the appropriate form of Work-Energy principle – Bodies character of motion analysis; – Forming of FBD and kinematical diagrams; – Determination of the system kinetic energy at the final position of motion; – Determination of the work done by external and internal forces during displacement of the system from the initial position to the final position. – Solution of equation with respect to unknown velocity (unknown distance traveled); – Results analysis. **"**Spur Gear geometry. Planetary gear train synthesis." Stages of work: – Zero spur gear geometry; – Positive spur gear geometry; – Analysis of Qualitative indicators of involute gearing: transverse contact ratio/specific sliding/ geometric coefficient of specific pressure; – Planetary gear train synthesis: velocity ratio equation, coaxiality condition, non-interference condition, assembly condition and other.	24

8. Teaching methods

Lectures, practices; individual consultations; student self-study with the help of tutorials published by chair; Olympiad.

9. Grading

The course is divided into four thematic modules. Each module is finished by control quiz.

There are two individual tasks. Each problem in the tasks must be defended. The defending is in form quiz that includes theoretical questions and problems.

Each problems of the tasks must be submitted and defended before deadline. After the deadline time, students do not obtain points for the problem solution and defending.

Students who do not collect more than 59 points during the term must pass exam in written form or as a quiz with theoretical questions and problems.

9. Points distribution between topics

9.1 Points in module system

Term 2

Sort of work		Number of points	Deadline	Fines and notes
Module 1. Statics				
CGW 1, problem 1	Problem independent solution (System of two rigid bodies equilibrium (2D))	5	6 week	Coefficient 0 for submitting and defending after date of the module work
	Defending of the problem	3	7 week	
Current control	Self-works during practices, independent solution of extra problems	5	1-6 week	Extra-problems can not be submitted after date of the module quiz
Module quiz Statics	Solution of short problems and answers to theoretical questions	25	7-8 week	Once For all students at the same time
Module 2. Kinematics				
CGW 1, Problem 2	Problem independent solution (Rigid body plane motion)	5	13	Coefficient 0 for submitting and defending after date of the module work
	Defending of the problem	3	13	
CGW 1, Problem 3	Problem independent solution (Particle compound motion)	5	15	
	Defending of the problem	3	16	
CGW 1, Problem 4	Problem independent solution (Body compound motion)	5	15	
	Defending of the problem	3	16	
Current control	Self-works during practices, independent solution of extra problems	15	8-16 week	Extra-problems can not be submitted after date of the module quiz
Module quiz Kinematics	Solution of short problems and answers to theoretical questions	25	16	Once For all students at the same time
	Total	100		

Term 3

Sort of work		Number of points	Deadline	Fines and notes
Thematic Module 3. Dynamics (62 points)				
CGW 2, Problem 1	Problem independent solution (Work-Energy principle for system of bodies motion analysis)	8	9 week	Coefficient 0 for submitting and defending after date of the module quiz
	Defending of the problem	6	10 week	
Current control	Self-works during practices, independent solution of extra problems, quizes after lectures	34	1-11 week	Extra-problems can not be submitted after date of the module quiz
Module quiz Dynamics	Solution of short problems and answers to theoretical questions	20	11 week	Once For all students at the same time
Thematic Module 4. Synthesis (38)				
CGW 2, Problem 3	Problem independent solution (Spur Gear geometry. Planetary gear train synthesis)	8	15	Coefficient 0 for submitting and defending after date of the module quiz
	Defending of the problem	6	16	
Current control	Self-works during practices, independent solution of extra problems, quizes after lectures	4	12-16 week	Extra-problems can not be submitted after date of the module work
Module quiz Synthesis	Solution of short problems and answers to theoretical questions	20	16	Once For all students at the same time
	Total	100		

The examination is carried out in case of refusal of the student from points of current testing and if he has the admission to exam. Maximum mark of the exam is 100 points.
The question paper of examination consists of :

1) Theoretical question – 50 points;
2) Problem 1- 25 points;
3) Problem 2 – 25 points.

9.2 Qualitative evaluation criteria

The amount of knowledge required to obtain a positive assessment.

Student should know:

- the basic laws of mechanics and the limits of their application;
- methods of equivalent transformation of systems of forces;
- conditions of equilibrium of systems of forces;
- general geometric properties of mechanical motions of point, body, mechanical system;
- classification and scope of mechanisms use;
- general methods of design and research of mechanisms;
- mathematical modeling of mechanical systems dynamics;
- methods of kinematic synthesis and analysis of mechanisms including aircraft engines units;
- methods of dynamic analysis and synthesis of mechanisms

The required amount of skills to receive a positive assessment.

The student must be able to:

- to formulate the tasks of mechanical research of technical systems;
- to construct a mathematical model that adequately reflects the mechanical state (motion, equilibrium) of a material object;
- to search for the forces of interaction of elements of mechanical systems at rest and motion;
- to search for the law of motion of elements of mechanical systems.
- use modern methods of kinematic and dynamic analysis for mechanisms research;
- make structural analysis of mechanisms;
- project kinematic diagrams of mechanisms according to structural, kinematic and dynamic conditions;
- use mathematical methods of gear mechanisms research;
- choose rational schemes of planetary gears for aircraft engineering.

9.3 Criteria for assessing student work during the semester

Satisfactory (60-74). Have a sufficient minimum of knowledge and skills. Perform and protect all tasks included in the calculation work. Know the equilibrium conditions for different types of force systems. Know what the kinematic and dynamic equations of translational, rotational and axis rotation and plane-parallel motion of a solid look like. Be able to release any mechanical system from the bonds and make a sufficient number of equilibrium equations (in the case of equilibrium of the mechanical system) or equations of motion (in the case of its motion). Be able to do structural analysis of mechanisms, synthesis of planetary, differential gear trains and lever mechanisms and determine mobility of mechanisms.

Good (75-89). Perform and protect in the time specified in the work program all tasks that are part of the calculation work. Know the equilibrium conditions for different types of force systems. Know what the kinematic and dynamic equations of translational, rotational and axis rotation and plane-parallel motion of a solid look like. Be able to release any mechanical system from the bonds and make a sufficient number of equilibrium equations (in the case of equilibrium of the mechanical system) or equations of motion (in the case of its motion). Show the ability to analyze the results of solving practical problems. Know and be able to put into practice methods of describing the motion (or equilibrium) of a mechanical system in generalized coordinates. (3rd semester). Be able to do kinematic analysis of lever mechanisms by means of analytical and graph-analytical methods. Be able to create dynamic model of mechanism. Be able to determine geometrical parameters of involute gears.

Excellent (90 - 100). It is unmistakable to execute and protect with maximum marks and within the time specified by the teacher, all tasks that are part of the calculation work. Full knowledge of basic and additional material. Navigate your textbooks and guides. Be able to deduce and explain any formula and prove any theorem provided by the program. To master the methods of mathematical modeling of the dynamics of complex mechanical systems in generalized coordinates (3rd semester). Show the ability to analyze the results of solving practical problems

National scale and ECTS grade

Total score	ECTS scale	Mark on national scale	
		exam, course project	credit
90 – 100	**A**	Excellent	Passed
83 – 89	**B**	Good	
75 – 82	**C**		
68 -74	**D**	Satisfactory	
60 – 67	**E**		
1 – 59	**FX**	Fail (exam repeating is possible)	Failed (credit repeating is possible)

Student which passed all modules, can take total rating score and not pass final test. If student is not agree with total rating score, he can improve it passing final test.

Total rating score is transformed into ECTS and National score using recommended grade scales

10. Procedural guidelines

1. Theoretical mechanics. Kinematics: Tutorial for self-education / V. N. Pavlenko, I. V. Bunyaeva, S. S. Vorozhko et al. – Kharkov: National Aerospace University named after N. Ye. Zhukovskiy «Kharkov Aviation Institute», 2012. – 96 p.
   http://library.khai.edu/library/fulltexts/metod/Pavlenko_Theoretical_Mechanics.pdf
2. Theoretical mechanics. Dynamics: Textbook / V. N. Pavlenko, I. V. Bunyaeva, S. S. Ternovskaya et al. – Kharkov: National Aerospace University named after N. Ye. Zhukovskiy «Kharkov Aviation Institute», 2013. – 184 p.
   http://library.khai.edu/library/fulltexts/metod/Theoretikal_Mechanik.pdf
3. Theoretical mechanics. Statics: Textbook / V.A. Oikin, O.Y. Kladova, V.N. Pavlenko, Y.A. Stetsenko. — Kharkov: National Aerospace University 'Kharkov Aviation Institute', 2010. – 84 p.
   http://library.khai.edu/library/fulltexts/m2011/Theoretical_Mechanics_Statics.pdf
4. Theoretical mechanics. Statics: Textbook / V. N. Pavlenko, I. V. Bunyaeva, S. S. Vorozhko et al. – Kharkov: National Aerospace University «Kharkov Aviation Institute», 2012. – 100 p.
   http://library.khai.edu/library/fulltexts/metod/Statics_new_Final.pdf

Lectures are supported by PowerPoint presentation. Handout referring to the actual topics is distributed during lectures and practices.

11. Recommended literature for the course

Basic

1. F.P. Beer and E.R. Johnston, Vector Mechanics for Engineers – Statics. Dynamics, McGraw Hill Book Company, 2003.

2. J.L. Meriam and L.G. Kraige, Engineering Mechanics – Statics. Dynamics, John Wiley & Sons, 2002.

3. John J. Uicker, Jr., Gordon R. Pennock, and Joseph E. Shigley, Theory of Machines and Mechanisms, Fifth Edition – McGraw-Hill series in mechanical engineering, 2017.

Auxiliary

1. R.S. Khurmi, J.K. Gupta, Theory of Machine - Eurasia Publishing House, 2015.

2. Thomas Bevan, The Theory of Machines – CBS Publishers and Distributors, 2016.

3. The Theory of Machines by Robert Ferrier McKay – Edward Arnold, London, 2017.

4. C.H. Jensen, J.D. Helsel, Engineering Drawing And Design. - McGraw-Hill Science, 7th Edition, 2015.

5. J. A. Collins, H. R. Busby, G. H. Staab, Mechanical Design of Machine Elements and Machines. - Wiley, 2nd Edition, 2018.

12. Information sources

Term 2 https://mentor.khai.edu/course/view.php?id=4701
Term 3 https://mentor.khai.edu/course/view.php?id=5820
http://elartu.tntu.edu.ua/bitstream/lib/26905/1/nove_TMM_angl_metod_2018-converted%20%281%29.pdf