NATIONAL UNIVERSITY OF ENGINEERING
COLLEGE OF MECHANICAL ENGINEERING
MECHANICAL ENGINEERING PROGRAM

MC417 – MACHINE MECHANICS

I. GENERAL INFORMATION

CODE	: MC417 Machine Mechanics
GRADE	: 6
CREDITS	: 4
HOURS PER WEEK	: 06 (4 Theory – 2 Practice)
PREREQUIREMENTS	: MC338 (Machine Dynamics)
CONDITION	: Mandatory

II. COURSE DESCRIPTION

The course prepares the student in the application of the concepts, methods and techniques of the analysis of simple and complex plane mechanisms. The analysis refers to the kinematic analysis, which consists on determining positions, velocities and accelerations of the mechanisms by graphical and analytical methods. As well as to the static and dynamic analysis of mechanisms, which determine the forces in the mechanisms considering the “static” forces and those from the movement, also by graphical and analytical methods. Se desarrollan maquetas de mecanismos a escala y se hace uso de programas de aplicación específica para simulación de movimientos de mecanismos.

III. COURSE OUTCOMES

The student:

1. Compares the concepts of machine, mechanism and structure, based on the function it performs.
2. Identifies the types of movement of the elements of a plane mechanism, based on the classification of allowed movements.
3. Establishes the relation between Cycle, Period and Phase of the movement, based on the definition of each one of them.
4. Distinguishes the components of a mechanism, based on the function or role they play.
5. Classifies the kinematic pairs, based on the types of movements they perform.
6. Classifies the kinematic pairs, based on the types of movements they perform.
7. Deduces the degrees of freedom of a plane mechanism, based on the Grubler criterion.
8. Represents the kinematic inversions of the plane mechanisms ("four bars" and "crankshaft"), according to the base and number of elements it contains.
9. Represents the kinematic trajectories of characteristic points of plane mechanisms, according to the movement they perform and with respect to whom they move.

10. Determines the positions of the dead points and change points in plane mechanisms (“four bars” and “crankshaft”), according to the movement condition.
11. Draws the kinematic diagrams of positions (velocities and accelerations) of plane mechanisms, based on the movement of the driven element, with respect to the driver element.
12. Outlines the equivalent mechanisms, based on the enlargement of rotating kinematic pairs. Replacement of upper kinematic pairs of two degrees of freedom (trailing pairs), and substitution by rolling pairs.
13. Calculates the velocities of simple plane mechanisms for points belonging to the same body, based on the Orthogonal Component Method.
14. Calculates the velocities of simple plane mechanisms, based on the Method of the Poles of Velocities or CIR.
15. Calculates the velocities and accelerations of simple plane mechanisms, based on the Relative Movement Method for different cases: points belonging to the same body, coincident points, bodies in direct contact with trailing pairs and rolling pairs.
16. Calculates the positions, velocities and accelerations of plane mechanisms, based on the Analytical Method.
17. Classifies the plane mechanisms, based on the possibility of calculating the accelerations by the Relative Movement Method: Simple mechanisms and complex mechanisms.
18. Calculates the velocities of low complexity plane mechanisms, based on the methods of Hirschhorn, Carter, Goodman and Hall & Ault.
19. Calculates the velocities and accelerations of high complex plane mechanisms, based on the Goodman and Hall & Ault Methods.
20. Applies the necessary knowledge for the kinematic design of mechanical systems.
21. Recognizes the types of force analysis in simple plane mechanisms.
22. Recognizes the concepts and fundamental principles of static and dynamic applied to mechanisms, bodies in equilibrium, forces and moments in connections.
23. Establishes the state of equilibrium (free-body equilibrium) in bodies subjected to two forces, three forces and four forces.
24. Recognizes the D'Alembert Principle and the concepts of: inertia forces, Moments of Inertia, turning radius, percussion center, oscillation center.
25. Determines las fuerzas en las conexiones de los mecanismos planos debido a fuerzas “estáticas” (Fuerza resistente principal, pesos), mediante métodos gráficos.
26. Determines the forces in the connections of the plane mechanisms due to "static" forces (main strength, weights), by means of graphical methods.
27. Determines the forces in the connections of the plane mechanisms by considering the forces besides the "dynamic" forces (inertial forces and torques), by means of graphic methods.
28. Constructs scale models of conceptualized mechanisms.
29. Uses specific programs of simulation of movements of mechanisms.

IV. LEARNING UNITS

1. DEFINITIONS / (06 hours)

Introduction. Kinematics, Statics, Kinetics. Analysis and Synthesis of mechanisms. Definition of machine, mechanism and structure. Differences between machine and mechanism. Definition of rigid body. Kinematic Chain

and Mechanism. Cycle, Period, Movement phase. Types of movements. Components of a mechanism. Links. Kinematic pairs. Classification of kinematic pairs. Classification of mechanisms.

2. MECHANISMS STRUCTURE / (06 hours)

Introduction. Schematization of mechanisms. Criterion of Grubler. Degrees of freedom. Kinematic inversions of the four-bar mechanism. Kinematic inversion of the crank-shaft mechanism. Cam mechanisms. Kinematic trajectories. Dead points and change points. Kinematic diagrams of positions, speeds, accelerations.

3. EQUIVALENT MECHANISM / (06 horas)

Introduction. Equivalent mechanisms by extension of kinematic pairs. Cases. Equivalent mechanisms by substitution of kinematic trailing pairs. Cases. Exercises.

4. VELOCITIES OF SIMPLE PLANE MECHANISMS BY GEOMETRIC PHYSICAL METHODS / (06 horas)

Introduction. Determination of velocities by the Orthogonal Component Method. Instantaneous Rotation Center Method: Definition of Speed Poles, Number of Poles of Velocities, Three-Center Theorem or Kennedy's Theorem, Poles of Velocities Determination. Classification. Determination of Velocities by the Method of the Poles of Velocities: through the Absolute Poles, through the Relative Poles. Exercises

5. VELOCITIES AND ACCELERATIONS OF SIMPLE MECHANISMS BY GEOMETRIC PHYSICAL METHODS / (18 hours)

Relative Movement Method for points belonging to the same body: Analysis of velocities. Analysis of accelerations. Exercises.

Case of Coincident Points. Points that belong to different bodies. Acceleration of Coriolis. Quick return mechanisms. Case of Coincident Points of bodies in Direct Contact by drag. Cam mechanisms. Exercises.

Mechanisms with bodies in direct contact by pure rolling. Cases. Exercises.

6. KINEMATICS OF COMPLEX PLANE MECHANISMS / (14 horas)

Definition. Classification. Mechanisms of Low Complexity, mechanisms of High Complexity. Methods.
Determination of velocities and accelerations of plane mechanisms of Low Complexity. Hirschhorn method. Carter method. Goodman's method. Method of Auxiliary points or Hall-Ault. Exercises.
Determination of velocities and accelerations of plane mechanisms of High Complexity. Goodman's method. Method of Auxiliary points or Hall-Ault. Auxiliary methods of Hirschhorn and Carter. Exercises.

7. KINEMATICS OF SIMPLE PLANT MECHANISMS BY ANALYTICAL METHODS / (04 hours)

Determination of velocities and accelerations by the Complex Polar Notation Method. Mechanism Cases: Mechanism of "crank-shaft", Mechanisms of "Crank-shaft" inverted, Mechanisms of rapid return, Mechanisms of four bars, Combination of basic mechanisms. Exercises.

8. DETERMINATION OF FORCES IN MECHANISMS BY GRAPHIC METHODS / (14 hours)

Introduction. Fundamental principles of the static and dynamic of mechanisms. Bodies in equilibrium. Forces and moments in connections. Equilibrium in bodies subjected to two forces, three forces and four forces. Forces of inertia. Principle of D'Alembert.
Determination of forces using the radial and tangential components method. Method of overlapping effects. Application of methods for dynamic analysis of mechanisms (inertial forces and torques).

9. DETERMINATION OF FORCES IN MECHANISMS BY ANALYTICAL METHODS / (02 hours)

Determination of forces by the analytical method for static and / or dynamic forces, using algebraic scalar equations. Use of matrices for solving equations. Exercises

10. COMPLEMENTARY CONCEPTS / (02 hours)

Moments of Inertia. Turning radius. Center of percussion. Center of oscillation. Experimental determination of the Center of gravity and moment of inertia of irregular bodies.

V. LABORATORY AND PRACTICAL EXPERIENCES

- Integrative monographic work on all topics covered in the course, related to the evaluation, kinematic and dynamic analysis of a mechanism.
- Construction of models of mechanisms and use of simulation programs of movements in mechanisms.

VI. METHODOLOGY

The course is developed in sessions of theories and practices in a sustained way. In the theory sessions, the teacher exposes the concepts, definitions, theorems and methods for their corresponding applications. In the practical sessions, several cases are solved for different configurations of mechanisms. For the preparation of the report, the guidelines for the development of the report and the use of simulation programs are presented. At the end of the course the student must present the integrating monographic work and expose. In all the sessions, the active participation of the student is promoted.

VII. GRADING FORMULA

Evaluation System “D”

$$\text{FORMULA FOR THE FINAL GRADE : } \quad FG = \frac{3AQP + 1Mo}{4}$$

AVERAGE OF QUALIFIED PRACTICES (WEIGHT: 3): AQP (only one decimal)
MONOGRAPH (WEIGHT: 1): Mo (natural number)

VIII. BIBLIOGRAPHY

[1] Ham, Crane, Rogers, Machine Mechanics.
[2] Robert L. Norton, Machinery Design Ed. Mc. Graw Hill, Mexico 2009.
[3] Hirschhorn Jeremy, Kinematic and Dynamic of Plane Mechanism, Ed. Mc. Graw-Hill. Madrid 1974.

[4] Hamilton H. Mabie & Fred W. Ocvirk, Mechanisms and Dynamics of Machinery, Ed. Jhon Wiley & Sons, 2nd Edition, New York 1963.
[5] Shigley Joseph Edward, Kinematic Analysis of Mechanisms, Ed. Mc Graw-Hill 4th Edition, New York 1983.
[6] Joseph Edward Shigley, Theory of Machines and Mechanisms, Ed. Mc. Graw-Hill, 1997.
[7] I. I. Artobolevski, Mechanisms in the Modern Technique (6 volumes), Ed. MIR – Moscú, 1976.