

**COURSE DATA****Data Subject**

|                      |   |
|----------------------|---|
| <b>Code</b>          | 34926   |
| <b>Name</b>          | Theory and design of machines and process equipment |
| <b>Cycle</b>         | Grade   |
| <b>ECTS Credits</b>  | 6.0   |
| <b>Academic year</b> | 2023 - 2024   |

**Study (s)**

| <b>Degree</b>                                      | <b>Center</b>         | <b>Acad. year</b> | <b>Period</b> |
|--|-----------------------|-------------------|---------------|
| 1404 - Degree in Industrial Electronic Engineering | School of Engineering | 2                 | Second term   |

**Subject-matter**

| <b>Degree</b>                                      | <b>Subject-matter</b>               | <b>Character</b> |
|--|-------------------------------------|------------------|
| 1404 - Degree in Industrial Electronic Engineering | 10 - Equipment design and materials | Obligatory       |

**Coordination**

| <b>Name</b>           | <b>Department</b>          |
|-----------------------|----------------------------|
| CARRILLO ABAD, JORDI  | 245 - Chemical Engineering |
| PASTOR ALCAÑIZ, LAURA | 245 - Chemical Engineering |

**SUMMARY**

This course is divided into two different parts. The first one is the basis of the Theory of Machines and Mechanisms, whereas the second one deals with the mechanical design of process equipment.

The most simple and widely used mechanisms are considered and in particular the basis for the analysis of planar mechanisms is introduced at both kinematic and dynamic points of view. In that sense there is a special emphasis on vectorial methods to calculate velocities and forces acting on a mechanism.

Subsequently rotating mass balancing is treated which is a basic aspects for machine design.

As far as the mechanical design of process equipment is concerned, the second part of the course is



dedicated to the design of equipment undergo pressure by establishing a clear difference between that working under pressure and that working under vacuum. There is also a unit dedicated to the mechanical design of towers used in the process industry. They have to be able to withstand the effects of wind and seismic activity. Finally the mechanical design of pipes is considered.

The mechanical design is performed using the standards from API-ASME (American Petroleum Institute and American Society of Mechanical Engineers) which are widely accepted.

The contents of the course are: Principles of Theory of Machines and Mechanisms and Mechanical design equipment, which are structured in the units listed in section Description of Contents.

The general objectives of the course are:

- To make use from a practical point of view of the concepts of Mechanics which have been seen in the subject of Physics I.
- To develop in students the ability to propose and solve numerical problems in which mechanisms appear as well as to interpret the results.
- To develop strategies to design mechanically the industrial equipment containing liquids and solids.
- Enhance students' skills in reasoning and systematic work.
- Promote and encourage those values and attitudes that must be inherent to engineers.

Theoretical lessons will be in Spanish and the practical classes in Spanish or Valencian, in agreement with the webpage of the Degree.

## PREVIOUS KNOWLEDGE

### Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

### Other requirements

To successfully pass the subject is necessary that students possess a series of prior knowledge at the level demanded in subjects studied previously. This knowledge comprises:

Mechanics

Materials science



## OUTCOMES

### 1404 - Degree in Industrial Electronic Engineering

- CG3 - Knowledge of basic and technological subjects that allows students to learn new methods and theories and provides them with versatility to adapt to new situations.
- CG4 - Ability to solve problems with initiative, decision-making skills, creativity and critical reasoning and to communicate and transmit knowledge, abilities and skills in the field of industrial engineering (with specific industrial electronics technology).
- CG6 - Ability to deal with specifications, regulations and mandatory standards.
- CG8 - Ability to apply the principles and methods of quality control.
- CG10 - Ability to work in a multilingual and multidisciplinary environment.
- CG11 - Knowledge, understanding and ability to apply the necessary legislation for practising professionally as a qualified industrial engineer.
- CG24 - Knowledge of the principles of the theory of machines and mechanisms.
- CG25 - Knowledge and use of the fundamentals of the strength of materials.

## LEARNING OUTCOMES

1. To know and understand the principles of kinematics and dynamics of mechanisms and machines (CG3, CG24, CG25).
2. To know the fundamentals and methodology of the kinematics of mechanisms and their application to the analysis of simple systems (CG3, CG4, CG24).
3. To assess the suitability of a mechanism design (CG4, CG6, CG11, CG24).
4. To select the appropriate equipment and/or element for a particular application and justify their choice (CG4, CG10, CG24, CG25).
5. To know and be able to select and size transport, handling and storage of solids and fluids systems (CG3, CG4, CG24, CG25).
6. To know and apply regulations and industry codes in the mechanical design of equipment and simple structural elements (CG6, CG8, CG11).
7. To know and apply principles of safety in the design of mechanical equipment and simple structural elements (CG6, CG8, CG11).

After completing the course, students will be able to:

- Calculate the degrees of freedom of a mechanism.
- Describe the operation of the most common single mechanisms.
- Determine if in a four-bar mechanism some of them can make a complete circuit.
- Calculate the position of the bars of a mechanism and/or their length.
- Calculate the relative velocity and acceleration between two points on a mechanism by using vectorial methods.
- Calculate the velocity and acceleration of the bars of a mechanism knowing the angular velocity and acceleration of the motor bar by using vectorial methods.



- Apply the Coriolis acceleration to calculate the acceleration of prismatic pairs showing rotation.
- Calculate the reactions in a bar mechanism and the torque or the external force that must be applied to statically balance it when known forces act on certain bars.
- Apply the principle of superposition to calculate the reactions in the joints of a bar mechanism and the force that statically balances it.
- Define the components of inertia of a bar that moves in the plane.
- Calculate the velocity and acceleration of different points of a mechanism when external forces are not balanced.
- Calculate the force that must be applied to a mechanism so that a desired kinematic state is produced.
- Perform a matrix analysis to determine the dynamics of a bar mechanism.
- Determine whether a system of rotating mass is balanced and calculate the mass to balance it.
- Determine if an engine is balanced.
- Sort the tensions that can occur in vessels containing fluids.
- List the different procedures for calculating the wall thickness of a pressure vessel.
- Calculate the wall thickness of a container and a head to withstand a certain pressure.
- Calculate the maximum working pressure of a vessel and a head made from plates of commercial thickness.
- Calculate the thickness of vacuum vessels.
- Determine the number of stiffening rings in vacuum vessels.
- Calculate the shear stress and bending moment due to wind for a column.
- Determine the period of actual vibration due to wind for a column and its maximum allowance.
- To design a tower to support its weight.
- Calculate the shear stress and bending moment of a column due to seismic loads.
- Determine if a column is able to withstand seismic loads in the area where it will be located.
- Calculate the effect of eccentricity in a column equipped with external accessories.
- Calculate the wall thickness of a column subjected to a combination of loads.
- Estimate the point of the tower where longitudinal and tangential stresses are equal.
- Make the most economical proposal of plate thickness at various heights of the tower.
- Calculate strengths in pipes due to changes in direction.
- Calculate the overpressure due to water hammer.

In addition to what has been said before, the course will encourage students to develop several social and technical skills, among which the following are noteworthy:

- Capacity for analysis and synthesis.
- Ability to argue from rational and logical criteria.
- Ability to communicate in a properly and organized manner.
- Ability to develop a problem in a systematic and organized manner.
- Ability to work and distribute the personal time.
- Ability to work in groups.





## DESCRIPTION OF CONTENTS

### 1. INTRODUCTION TO THE THEORY OF MACHINES AND MECHANISMS. BASIC CONCEPTS.

Basic concepts and general definitions. Degrees of freedom of a mechanism. Kinematic Inversions. The Grashof condition. Mechanical advantage. Dead point. Kinematic diagrams. Practical application of different mechanisms: Four-bar mechanisms; Crank-rocker mechanism; Slider-crank mechanism.

### 2. GEOMETRIC ANALYSIS OF PLANAR MECHANISMS

Introduction. Analytical methods: Ravens method.

### 3. KINEMATIC ANALYSIS OF PLANAR MECHANISMS BY VECTORIAL METHODS

Introduction. Speeds on the machines: Position, displacement and velocity of a point; Position, displacement and angular velocity of a solid; Method of relative velocity. Accelerations in machines: Acceleration of a point; Relative acceleration of two points either; Acceleration of two points on a rigid body; The Coriolis component of acceleration.

### 4. DYNAMIC ANALYSIS OF PLANAR MECHANISMS

Introduction. Static in machines: Transmission of forces in mechanisms; Conditions for static equilibrium; Principle of superposition; Alternative method to the principle of superposition. Dynamic Analysis: External actions; Internal actions or reaction; Dynamic equilibrium of a particle with mass; Components of inertia of a bar in planar motion; Components of inertia of a planar bar. Dynamic analysis. Matrix method.

### 5. MASS BALANCING

Introduction. Balancing of rotors: Static equilibrium; dynamic equilibrium; Analytical method to calculate the mass balancing. Balancing of engines: Single-cylinder engines; Multi-cylinder engine.

### 6. MECHANICAL DESIGN OF VESSELS UNDER INTERNAL PRESSURE

Introduction. Vessels under internal pressure. Mechanical design of vessels under internal pressure: Design of tanks containing gases; Design of tanks containing liquids; Vessels with intermediate walls; Thick-walled vessels; Methodology to design the thickness of a vessel under internal pressure. Solid storage systems.

**7. MECHANICAL DESIGN OF VESSELS UNDER EXTERNAL PRESSURE**

Introduction. Design of cylindrical vessels. Design of conic shells and heads. Design of spheres and spherical, ellipsoidal and torispherical ASME code heads: Spherical shells and heads; ellipsoidal 2:1 and torispherical heads. Stiffening rings design: Number of stiffening ring; Design of stiffening rings.

**8. HIGH TOWERS MECHANICAL DESIGN**

Introduction. Design of towers to support the wind action or pressure: Design for a tower with constant wind load ( $P_w$ ); Design for a tower with variable diameter; Design for a constant diameter tower and a wind load that varies with altitude. Design of towers to support their weight. Tower design to withstand vibration. Design of towers to withstand seismic loads. Design of towers to withstand eccentric loads. Elastic stability conditions: Tray supports: stiffeners, tubes for fluid rise or fall. Combination of stresses: Estimation of the distance where the longitudinal and tangential stresses are the same. Skirt support design.

**9. MECHANICAL DESIGN OF PIPES**

Introduction. Wall thickness in pipes. Pipe support. Water hammer in pipes.

**WORKLOAD**

| ACTIVITY                                     | Hours         | % To be attended |
|--|---------------|------------------|
| Theory classes                               | 30,00         | 100              |
| Classroom practices                          | 30,00         | 100              |
| Development of group work                    | 10,00         | 0                |
| Preparation of evaluation activities         | 15,00         | 0                |
| Preparing lectures                           | 28,50         | 0                |
| Preparation of practical classes and problem | 35,00         | 0                |
| Resolution of online questionnaires          | 1,50          | 0                |
| <b>TOTAL</b>                                 | <b>150,00</b> |                  |

**TEACHING METHODOLOGY**

The development of the course is structured around the theory classes and practical activities. Some of these activities will be evaluated and will contribute to the final mark.

In the theory classes (CG3, CG6, CG7, CG11, CG24, CG25) lecture model will be used to explain the most complex or difficult notions and always during periods of less than 30 minutes. Many of the theoretical concepts will be prepared by students working with the material provided to them.



Problems (CG3, CG4, CG6, CG8, CG10, CG11, CG24, CG25) will be developed in practical class sessions following two models. Some problems will be solved by the teacher so that students find out the way to address them, while others will be solved by students, individually or in groups under the supervision of the teacher. After the work, the problems will be collected, analyzed and corrected by the teacher or the students.

The proposed work for the students (CG3, CG4, CG6, CG8, CG10, CG11, CG24, CG25) will be of several types: Questions, short exercises or problems similar in complexity to those of the exams. All of these activities will be done in class or at home, and will have a timetable for completion and delivery, their contribution to the final mark being established as well. After correction, the students will be informed of their results and will be given with a summary of the most common mistakes.

## EVALUATION

In the first call, the evaluation of student learning will be carried out following two models:

1. Continuous assessment (modality A)
2. From the mark of a final exam and a delivery (modality B).

**Modality A:** three individual tests carried out by the students throughout the course will be valued. The evaluation for modality A will be carried out considering two independent blocks: Block I: subjects 1 to 5; Block II: topics 6 to 9. A test will be done for each block. The third test can deal with any topic and will be more practical. The final grade for this modality A will be calculated following the following criteria:

- 50% Grade of the test corresponding to Block I (CG3, CG4, CG6, CG11, CG24, CG25)
- 40% Grade of the test corresponding to Block II (CG3, CG4, CG6, CG11, CG24, CG25)
- 10% Grade of the third test (CG3, CG4, CG6, CG8, CG10, CG11, CG24, CG25)

The requirements to pass for modality A) are: to have a mark of 4 or higher in each of the three tests and a final average mark of 5 or higher. Each test will have a test part of theoretical-practical questions and another part of problems. A minimum mark of 3 out of 10 in the test part or 7 out of 10 in the problem part will be required in order to pass the exam.

Failure to pass a partial exam of a block will mean the loss of the possibility of sitting the same block at the first call.

Throughout the course, different exercises will be carried out which may increase the mark obtained in each of the blocks by up to 1 point.

The mark corresponding to each of the blocks will be kept throughout the course in this modality.



**Modality B:** the student must take a final exam of the two blocks, which will have a part of test and differentiated problems, differentiated, on the date of the first call, which will count for 90% of the final mark. The remaining 10% will be obtained from the practical activity (this activity corresponds to the third test of modality A). The requirements for the written test in modality B are the same as those required to pass modality A.

In order to pass the course, the final mark must be equal to or higher than 5.

In any case, the evaluation system will be governed by the provisions of the Regulations for Evaluation and Qualification of the University of Valencia for Degrees and Masters  
([https://webges.uv.es/uvTaeWeb/MuestraInformacionEdictoPublicoFrontAction.do?accion=start & idEdictorSelected=5639](https://webges.uv.es/uvTaeWeb/MuestraInformacionEdictoPublicoFrontAction.do?accion=start&idEdictorSelected=5639))

## REFERENCES

### Basic

- Fundamentos de Teoría de Máquinas. A. Simón i altres (Bellisco, 2004)
- Pressure Vessel Handbook. 14th Ed. E. F. Megyesy (PV Publishing, 2008)

### Additional

- Resistencia de materiales L. Ortiz Berrocal. (McGrawHill, 2007). Libro en formato electrónico para miembros de la UV.
- A Brief Illustrated History of Machines and Mechanisms. Emilio Bautista Paz i altres (Springer, 2010). Libro en formato electrónico para miembros de la UV.
- Diseño de maquinaria: síntesis y análisis de máquinas y mecanismos R. L. Norton (McGrawHill, 2009)
- Chemical Engineering. Vol 6 J. M. Coulson, J. F. Richardson (Pergamon Press, 1983)
- Problemas resueltos de teoría de máquinas y mecanismos J. L. Suñer i altres (Editorial UPV, 2001)