240011 - Linear Algebra

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2017
Degree: BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 6
Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: Garcia Planas, Maria Isabel
Others:

Degree competences to which the subject contributes

Specific:
1. Capacity to solve mathematical problems that can appear in engineering. Aptitude to apply knowledge about:
   - Linear algebra; geometry; differential geometry; differential and integral calculus; differential equations and derived
   - Partial equations; numerical methods; numerical algorithm; statistics and optimisation.

Transversal:
04 COE. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning
   outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of
   specialization.
02 SCS. SUSTAINABILITY AND SOCIAL COMMITMENT. Being aware of and understanding the complexity of social and
   economic phenomena that characterize the welfare society. Having the ability to relate welfare to globalization and
   sustainability. Being able to make a balanced use of techniques, technology, the economy and sustainability.
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects
   pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
07 AAT. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-
   appraisal. Choosing the best path for broadening one's knowledge.

Teaching methodology

In the theoretical sessions, the basic theory is presented by showing them the most important notions and results by
means of examples.
In the practical sessions, the exercises and problems which has been solved previously by the students are commented
in class in order to consolidate the concepts that have been seen in the theoretical class. Moreover, modelling problems
are presented to see the importance of algebra when solving applied science and engineering problems.
In the workshop sessions the students work with the software Matlab (or Octave) mathematical tool in order to introduce
effective methods for calculating ranges matrices, solving systems of equations and computation of eigenvalues and
eigenvectors.
The students will present their work by means the e-portfolio, a guide will be show in class.

Learning objectives of the subject
The objectives are:

i) To provide a comprehensive treatment of the Theory of Matrices required by the various technological disciplines. In this sense the concepts and techniques that are introduced are illustrated with elementary engineering applications. Suitable for the treatment of cases with high-dimensional tools are presented in the same sense.

ii) Sign in handling matrices for solving systems of equations apply to large differences in different areas of engineering. Thus applications of matrix theory to various fields such as Markov chains, economic models, numerical analysis etc. is.

iii) Acquisition of knowledge and basic principles on the geometry of vector spaces.

iv) Understanding the role of linear applications in the context of vector spaces and their relationship with matrix algebra.

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>56h</th>
<th>37.33%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Hours small group:</td>
<td>4h</td>
<td>2.67%</td>
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<tr>
<td></td>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Self study:</td>
<td>90h</td>
<td>60.00%</td>
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</tbody>
</table>
### Content

#### UNIT 1: Algebraic Structures

**Learning time:** 45h
- Theory classes: 4h
- Practical classes: 6h
- Laboratory classes: 2h
- Guided activities: 2h
- Self study: 31h

**Description:**
- **Complex Numbers:** binomial and exponential forms; operations; application to alternating currents (phasors, impedance, reactive power).
- **Polynomials and Rational Fractions:** roots; Taylor formula; factorization in first polynomials; decomposition of a rational fraction into partial fractions; applications (primitive Laplace and Z antitransform, ...).
- **Matrices and Determinants:** operations and particular types of matrices; determining a square matrix (elemental properties, calculation); rank of a matrix; Applications to Linear Control Systems (controllability, controllability index, ...).
- **Systems of equations:** compatible/incompatible determined/undetermined; resolution (Gauss, Rouche-Frobenius, Cramer); examples and applications (Kirchoff's laws, network flows, patterns of diet, lattice model for the distribution of temperature, Leontief economic model, ...); matrix inversion; resolution with Matlab (LU decomposition, ...).

#### UNIT 2: VECTOR SPACES AND LINEAR APPLICATIONS

**Learning time:** 45h
- Theory classes: 8h
- Practical classes: 6h
- Laboratory classes: 2h
- Guided activities: 2h
- Self study: 27h

**Description:**
- **Vector Spaces:** definition; examples (vector physical magnitudes, electrical magnitudes, vibration, demographic cohort models, ...); bases, coordinates, dimension; matrix representation of a vector and a family of vectors, its rank; changes of coordinates, change of basis matrix; Examples and Applications (color codes crystallographic networks geological ternary diagrams, ...). Subspaces VECTOR: adapted bases; subspaces defined by equations and generators; application to circuit analysis (to mouth mesh node voltages); and sum intersection subspace directly added; Application to Linear Systems Control (controls reachable states as available).
- **Ordinary Scalar Product:** definition, orthonormal bases
- **Linear Applications:** definition and determination; a linear array; base change; rank and determinant; kernel and image; Application to Linear Systems Control (controllability matrix of observability, Kalman decomposition); injectivity, bijectivity and completeness; isomorphisms.
# UNIT 3: REDUCTION OF LINEAR APPLICATIONS

**Description:**
DIAGONALIZATION: invariant subspaces; vectors and eigenvalues; examples and applications (the Google search engine, modes of vibration, main directions of stress / strain, principal axes of inertia, stationary distributions in discrete systems, pulse a linear control system, ...); diagonalizable matrices; computation of eigenvalues and eigenvectors, characteristic polynomial, algebraic and geometric multiplicity; diagonalization criteria, specific cases (different symmetric eigenvalues circulating ...); applications (inertia tensor, tension stress and strain, magnetic coupling matrices, ...); determination of the signs of the eigenvalues of symmetric matrices; applications (determination of relative extremes, conical classification, ...); computation of eigenvalues and eigenvectors using Matlab and / or Octave; NO DIAGONALIZABLE MATRICES: Jordan canonical form, Jordan bases.

## Learning time: 30h
- Theory classes: 8h
- Practical classes: 4h
- Laboratory classes: 2h
- Guided activities: 1h
- Self study: 15h

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# UNIT 4: APPLICATION OF LINEAR ALGEBRA TO SOLVE DISCRETE LINEAR SYSTEMS

**Description:**
DIFFERENCE EQUATIONS: homogeneous linear EED; resolution using characteristic polynomial; examples (Fibonacci, price swings, ...).
DISCRETE DYNAMIC SYSTEMS: resolution by the powers of the system matrix; calculation in the diagonalizable case; dynamic properties (dominant eigenvalue, asymptotic behavior, equilibrium points, stability, ...); examples and applications: population patterns, taken/predator index accessibility of the nodes of a network, ...).

## Learning time: 30h
- Theory classes: 4h
- Practical classes: 9h
- Laboratory classes: 0h
- Guided activities: 1h
- Self study: 16h

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## Planning of activities

### WORKSHOP OF ALGEBRA

**Hours:** 10h
- Laboratory classes: 10h

**Description:**
Introduction to Matlab, introduction of vectors and matrices to the computer, symbolic manipulation, polynomials, zeros of polynomials, solving systems of linear equations. Obtention of eigenvalues and eigenvectors.

**Support materials:**
Set of practices
The assessment will consist of four grades obtained by:

- A partial quarter average test (EP) done on the date determined by the school.
- A test on Algebra Workshop (TE) held at the time of the workshop.
- Control of guided activities (e-portafoli) (AD)
- The final exam (EF) also on the date set by the School.

The final grade (NF) is calculated as follows:

Final mark (NF) = + 20% AD + 10% TE +30% EP +40% EF

If the student fails the course, he has the possibility of being re-evaluated by the date set by the school (July).

The re-assessment note will be calculated as follows

NF= 20% AD + 10% ET + 70% ER

where ER is the mark obtained in the examination of re-evaluation.

Regulations for carrying out activities

IT material will just be allowed to use in the algebra workshop evaluation.
In all the other evaluations, a one sheet personal formulary will be allowed to check. (one DIN. A4 sheet maximum).
Calculator may not be used.

Bibliography

Basic:


Complementary:


Others resources:

In the Atenea website, there are resources such as problem list, with resolutions; collection of past exams, with resolutions.
Teacher e-Portfolio