UNICUSANO ROME

**Code:** ING-FIS/01 **Credits:** 9
**Matter:** Physics
**Main language of instruction:** Italian
**Other language of instruction:** English

**Teaching Staff**

**Head instructor**
**Prof. Daniele Barettin - daniele.barettin@unicusano.it**

## Introduction

*Objective of the course :*

The course provides the basics of Mechanics and Thermodynamics necessary to deal with the study of the different themes of the various Engineering sectors. The simplest situations are first presented by studying first kinematics and dynamics in the approximation of the material point and then the fundamental principles of conservation and non-conservation of mechanical energy. Subsequently, the learned models are applied to the mechanics of complex systems and to three-dimensional systems. Finally, an introduction to the basic principles of thermodynamics is presented. In the course an equivalent importance is given to the theoretical part, which provides a rigorous introduction to the models, with a complete mathematical treatment and a wide range of analyzed examples, and to the application part, consisting of a vast collection of exercises on the studied arguments.

The E-tivity to be carried out are proposed in the form of Original Problems and Self-Assessment Tests, both being necessary for a deeper understanding of some topics of the course and useful for the final evaluation.

The fundamental purpose of the course is to provide the student with a method of analysis and resolution of paradigmatic problems that can be subsequently extended to realistic and complex situations.

## Objectives

The first subject of the course is the study of kinematics in the approximation of material points. The first mechanical quantities are introduced, such as position, speed and acceleration, first from a strictly formal and mathematical point of view and then analyzing the fundamental motions of the material point, starting from the simplest case of uniform straight motion in the one-dimensional case, up to study the most complex cases in three-dimensional space. Basic problems of classical physics are also introduced, such as harmonic motion or damped motion. This first topic is the basis of the next part of the program, which develops what is the effect - kinematics and therefore movement - from the point of view of the causes of the movement itself: the study of dynamics of material point. The second principle of dynamics - Newton's law - is introduced and solved in detail for the fundamental forces of classical mechanics, such as weight, elastic force and friction forces. Great attention is also given here to some fundamental problems of mechanics, such as situations of static and dynamic equilibrium, the inclined plane, the simple pendulum (harmonic oscillator), and the resolution of Newton equation in the case of centripetal forces.
The next step is the introduction of fundamental concepts, always within the framework of the approximation of material points, such as Work of a force, kinetic energy, potential energy. The latter is analyzed in the case of the main conservative forces, thus providing the basis for stating the conservation of mechanical energy theorem .

Subsequently, the approximation of material points is abandoned to study the kinematics and dynamics of complex systems of material points and bodies. For this purpose new mechanical quantities are introduced, such as the angular momentum and the momentum of a force, necessary for example to interpret the rotary motions of a system of points or of an extended body, and some theorems (of the center of mass, of the angular momentum, Koenig), which are the basis to model the dynamics and kinematics of systems and rigid bodies.
The last part of the course is devoted to an introduction to thermodynamics. The systems, quantities and thermodynamic transformations are illustrated. New concepts such as heat are explained also showing a more complete point of view on some magnitudes already

studied in mechanics, such as energy and work. Ample space is devoted to the study of the first principle of thermodynamics, in particular with regard to the approximation of perfect gases, with a complete analysis of their main transformations (isobaric, isochoric, isothermal, adiabatic).

**Competencies:**

- Knowledge and understanding:
• understanding of the terminology used in point mechanics, extended systems, rigid bodies and Thermodynamics;
• knowledge of the fundamental laws governing the dynamics and statics of bodies and the thermodynamic transformations.

- Application of knowledge:
• identify specific solutions to a problem of kinematics, statics, dynamics and thermodynamics;
• understanding of theories concerning classical physics.

- Ability to draw conclusions:
• resolution of analytical and numerical problems concerning the mechanics of point and extended bodie, both in equilibrium configurations (state and dynamic) and in configurations out of equilibrium, and of problems within thermodynamic transformations.

- Communication skills:
• development of a correct, rigorous and understandable scientific language that allows the knowledge and techniques acquired during the course to be presented clearly and completely.

- Ability in learning:
• apply the acquired knowledge to solve original problems concerning mechanics and thermodynamics.

## Syllabus

*Course program:*

**Subject 1.**
This module illustrates the fundamental quantities of kinematics and introduces the approximation of material points. Fundamental concepts of Mathematical and Algebra Analysis are recalled in order to give the student means to derive the main equation of motion, from the simplest cases, such as uniform one-dimensional linear motion to more complex cases of three-dimensional motion. Both the direct problem is introduced, so how from a motion law to obtain all the kinematic quantities of the material point, and the inverse problem, i.e. how from the acceleration we can derive the motion laws in different situations and with different initial conditions .

**Subject 2.**
In this module the concept of Force is introduced, and the Second Law of Dynamics (Newton's Law) is explained in the approximation of material point. The methods of analysis of a static and dynamic equilibrium situation, the calculation of constraint reactions and of vector sum of forces are illustrated. The calculation of the Newton equation is explained for the main natural forces, such as the weight force, the elastic force, the sliding and viscous friction forces and the tensions of not-extensible wires. Some basic models used in classical mechanics are also presented, even in the case of more complex situations of material point approximation, such as the inclined plane, the simple pendulum or harmonic oscillator and the effect of centripetal forces.

**Subject 3.**
In this module the concepts of work and energy are introduced and developed. The kinetic energy theorem and its use for calculating work is demonstrated. The concepts of conservative and non-conservative forces are explained with mathematical rigor and practical examples. The concept of Potential Energy is introduced with numerous applications in the case of conservative forces (weight force, elastic force). We demonstrate the theorem of conservation of mechanical energy and illustrate its use for the resolution of dynamic problems at equilibrium and out of equilibrium both in the case of conservative forces and in the presence of dissipative effects due to non-conservative forces.

**Subject 4.**
In this module students are gradually introduced to the abandoning of the approximation of a single material point by introducing the study of kinematics and dynamics of complex systems of material points and rigid bodies. In this perspective, abandoning the hypothesis of a purely translation of the material point, we introduce the quantities suitable to describe a complete motion (translation and rotation) of a system of points, such as the Angular Momentum and the Momentum of a Force, starting always from the simple case of material point and then expanding the concept to complex cases. The fundamental theorems for the study of complex systems of material points and rigid bodies are introduced both from a strictly mathematical point of view and with the use of numerous examples, such as the theorem of angular momentum, of center of mass, the two Koenig's theorems and the theorem of mechanical energy. In particular, in the study of rigid bodies, the concepts of density of a body and of inertia momentum are introduced and illustrated, together with the Hygens-Steiner theorem.
**Subject 5.**
In this module some basic concepts of thermodynamics are introduced. First the different thermodynamic systems and the transformations and thermodynamic variables are illustrated, to then explain the concepts of work, heat and energy from the point of view of thermodynamics, completing what we have seen in mechanics. The first principle of thermodynamics is then explained, in particular in the case of the approximation of perfect gases. In this context, the main thermodynamic transformations of perfect gases (isobaric, isochoric, isothermal and adiabatic) are analyzed in detail.

**Evaluation system and criteria**

Verification of the achievements is carried out through evaluation of the E-tivity and of a Profit Exam, which consists of a written test.

**Bibliography and resources**

1. *Materials to consult:*

Teaching materials by the teacher.

Material on the course website is divided into different sections including lecture notes, exercises, video-lessons and e-tivity.
The lecture notes are structured in order to provide a summary of the topics covered, which are then developed in video lessons.

2. *Recommended bibliography:*
   *Halliday-Resnick,*
   *Foundamental of Physics, Jean Walker Editions.*