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Physics II

Academic Year: (2023 / 2024) **Review date: 19-12-2023**

Department assigned to the subject: Physics Department

Coordinating teacher: IÑARREA LAS HERAS, JESUS

Type: Basic Core ECTS Credits : 6.0

Year : 1 Semester : 2

Branch of knowledge: Engineering and Architecture

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Mathematics, Physics and Chemistry (high-school level)

SKILLS AND LEARNING OUTCOMES

RA1: Acquire knowledge and understanding of the basic general fundamentals of engineering and biomedical sciences.
RA2: Be able to solve basic engineering and biomedical science problems through a process of analysis, identifying the problem, establishing different methods of resolution, selecting the most appropriate one and its correct implementation.
CB1: Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2: Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CG1: Adequate knowledge and skills to analyse and synthesise basic problems related to engineering and biomedical sciences, solve them and communicate them efficiently.
CG3: Knowledge of basic scientific and technical subjects that enables them to learn new methods and technologies, as well as providing them with great versatility to adapt to new situations.
CG4: Ability to solve problems with initiative, decision-making, creativity, and to communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the biomedical engineer's activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG8: Ability to solve mathematical, physical, chemical and biochemical problems that may arise in biomedical engineering.
CG12: Ability to solve mathematically formulated problems applied to biology, physics and chemistry, using numerical algorithms and computational techniques.
ECRT2: Ability to solve physical problems that may arise in engineering and biomedicine. Ability to apply knowledge of: kinematics; dynamics; electromagnetism; waves; small oscillations; thermodynamics.
CT1: Ability to communicate knowledge orally and in writing to both specialised and non-specialised audiences.

OBJECTIVES

The course consists of two parts. The first one is about the thermodynamics of living systems, i.e., the study of energy transformation in the biological science. The second part introduces some basic physical concepts in Medical Physics, mainly related to the interaction of radiation with matter, atomic and nuclear structure.

The following competences and skills should be acquired:

- Ability to know and understand the basic laws and concepts of thermodynamics, focusing on its applications to biochemistry and biology
- Ability to understand the basic elements of the interaction of radiation with matter, atomic and nuclear structure essential in Medical Physics
- Ability to understand and use the mathematics involved in the physical models
- Ability to understand and use the scientific method
- Ability to understand and use the scientific language
- Ability to develop skills to solve problems

- Ability to use scientific instruments and analyze experimental data
- Ability to retrieve and analyse information from different sources
- Ability to work in a team.

DESCRIPTION OF CONTENTS: PROGRAMME

PART I BIOLOGICAL THERMODYNAMICS

1. The First Law of Thermodynamics
   - 1.1 Introduction to Thermodynamics. Concepts and definitions
   - 1.2 The zeroth law of Thermodynamics. Temperature. Equilibrium states
   - 1.3 The first law of Thermodynamics. Joule experiment
     - 1.3.1 Internal energy
     - 1.3.2 Work and heat
     - 1.3.3 Heat capacity. Specific heats
     - 1.3.4 Phase changes
     - 1.3.5 The first law in operation. Applications to ideal gases
   - 1.4 Enthalpy. Standard state. Examples from biochemistry
2. The Second Law of Thermodynamics. Entropy
   - 2.1 Introduction. Statement of Kelvin-Planck
   - 2.2 Heat engines
   - 2.3 Refrigerating engines
   - 2.4 Cycle of Carnot. Theorem of Carnot
   - 2.5 Entropy. Heat and entropy. Equilibrium. Reversible and irreversible processes
   - 2.6 Entropy of the universe
   - 2.7 Cycles of ideal gases
3. Free energy. Theory
   - 3.1 Introduction. Free energy
     - 3.1.1 Definition
     - 3.1.2 Direction of a spontaneous process
     - 3.1.3 Free energy and work
     - 3.1.4 Free energy and the second principle of Thermodynamics. Protein denaturation
     - 3.1.5 Free energy of an ideal gas. Standard state
   - 3.2 Chemical potential
     - 3.2.1 Chemical work
     - 3.2.2 Chemical potential
     - 3.2.3 Chemical potential of an ideal gas
   - 3.3 Thermodynamics of chemical reactions
     - 3.3.1 Free energy of a reaction. Criterion of spontaneity
     - 3.3.2 Concentration dependence of the free energy of a reaction
     - 3.3.3 Equilibrium constant
4. Energetics of living systems (free energy applications)
   - 4.1 Metabolism. Respiration and Photosynthesis
     - 4.1.1 Photosynthesis
     - 4.1.2 Respiration. Glycolysis and the citric acid cycle
     - 4.1.3 Oxidative phosphorylation and ATP hydrolisis
   - 4.2 The Aqueous and Ionic Equilibrium of the Living Cell
     - 4.2.1 Osmosis
     - 4.2.2 Electrochemical equilibrium. Electrochemical potential. Nernst equation
     - 4.2.3 Donnan equilibrium
   - 4.3 Membrane Transport. Passive and Active Transport
5. Statistical Thermodynamics
   - 5.1 Introduction
   - 5.2 Kinetic Theory of Ideal gases
     - 5.2.1 Pressure. Energy equipartition principle
     - 5.2.2 Maxwell distribution of velocities
   - 5.3 Statistical Definition of Entropy
   - 5.4 Maxwell-Boltzmann Distribution. Partition Function
   - 5.5 Thermodynamic Functions

PART II SOME ELEMENTS OF MEDICAL PHYSICS

6. Radiation and the Atom
   - 6.1 Radiation
     - 6.1.1 Electromagnetic radiation
     - 6.1.2 Particulate radiation
   - 6.2 Structure of the Atom
     - 6.2.1 Electronic structure
     - 6.2.2 Radiation from electron transitions
7. Interaction of Radiation with Matter

7.1 Particle interactions
7.1.1 Excitation, ionization and radiative losses
7.1.2 Neutron interactions
7.2 X- and Gamma-Ray Interactions
7.2.1 Rayleigh scattering
7.2.2 Compton scattering
7.2.3 The photoelectric effect
7.2.4 Pair production
8. Radioactivity and Nuclear Transformations
8.1 The atomic nucleus
8.2 Nuclear stability. Radioactivity: alpha, beta and gamma decay
8.3 Nuclear binding and mass defect. Nuclear fission and fusion
8.4 Radioactive decay law. Half-life
8.5 Physical and biological dosimetry

LEARNING ACTIVITIES AND METHODOLOGY

* Lectures where the theoretical concepts are explained

The lecturer will provide a file with the following information (1 week in advance):
- Main topics to be discussed during the session
- Chapters/sections in each of the text books provided in the bibliography where the student can read about these topics

* Activities in groups (2-3 people) to solve problems:

The main skills to be acquired in these activities are:
- To understand the statement of a problem (for instance drawing an scheme that summarizes the statement)
- To identify the physical phenomenon involved in the statement and the physical laws involved
- To develop an strategy to reach the objective (for instance breaking the problem in small subproblems)
- To be careful in the use of mathematics
- To be able to make a critical analysis of the results (is the final number sensible?, are the dimensions consistent?)

* Small tasks focused to search for scientific information from different sources (mainly internet)

* Laboratoy sessions (~24 students divided in 2 people groups)

The main skills to be developed in this activity are:
- To understand that physics is an experimental science and they can reproduce the laws that have been theoretically explained in the lectures
- To use scientific instruments and to be careful in its operation
- To be careful in the acquisiton of experimental data
- To learn the basis for the management of a scientific data set
- To be able to write a report with the main results of the experiment
- To be able to discuss in a critical way the experimental results: have we achieved the goals of the experiment?

ASSESSMENT SYSTEM

* Laboratory sessions (15% of final mark)

Attendance to the laboratory sessions is compulsory. The students must also write a report on each of the experiments carried out in every session. The mark will be common for all the members of each group.

* Activities in groups (25% of final mark)

The evaluation will take into account attendance and student attitude, short test exams periodically proposed, as well as the student performance in the proposed activities.

* Written exam (60% of final mark)

The exam will take place at the end of the semester and it will be common for all the students.

Contents:

- Problems to be solved covering the main topics of the program.
- Short theoretical questions.

A minimum score of 3 over 10 will be required to pass the course.

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- D.T. HAYNIE BIOLOGICAL THERMODYNAMICS, Cambridge University Press (2003).
- MIRAVENT, D.J., LLEBOT RABAGLIATI, J.E., PÉREZ GARCÍA, C. FISICA PARA LAS CIENCIAS DE LA VIDA, McGraw Hill, 2008
- TIPLER, P.A., MOSCA PHYSICS for Scientists and Engineers, Volume 1, G. W.H. Freeman, 2007

ADDITIONAL BIBLIOGRAPHY

- BUSHBERG, J.T., SEIBERT, J.A., LEIDHOLT, E.M., BOONE, J.M. THE ESSENTIAL PHYSICS OF MEDICAL IMAGING, Lippincott, Williams and Wilkins, 2002
- R. GLASER BIOPHYSICS, Springer-Verlag (2001).