

Academic Year: ( 2017 / 2018 )

Review date: 16-04-2017

Department assigned to the subject: Physics Department

Coordinating teacher: MARTIN SOLIS, JOSE RAMON

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)

**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 hydrolysis
  - 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)

\* Laboratory 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 acquisition 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 (assignments, 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).