UNICAMILLUS

Medicine and Surgery degree course

Teaching**: PHYSICS STATISTICS AND INFORMATION PROCESSING**
SSD: PHYS-06/A; MED-24/A; INF-05/A; INF-01/A
Coordinator: Prof. Eleonora Nicolai e-mail: eleonora.nicolai@unicamillus.org
CFU: **17**

Teaching module: **Applied Physics**
SSD: **PHYS-06/A - 5 CFU**

Prof. Gian Marco Contessa (1 CFU) e-mail:gianmarco.contessa@unicamillus.org
Prof. Eleonora Nicolai (1 CFU) e-mail: eleonora.nicolai@unicamillus.org
Prof. Luca Burratti (2 CFU) e-mail: luca.burratti@unicamilllus.org
Prof. Sara Spadone (1 CFU) e-mail: sara.spadone@unicamillus.org

Teaching module**: Medical Statistics**
SSD**: MED-24/A – 5 CFU**

Prof. Anne Rutjes (2 CFU) e-mail: anne.rutjes@unicamillus.org
Prof. Fabrizio Carinci (3 CFU) e-mail: fabrizio.carinci@unicamillus.org

Teaching module: **Information Technology**
SSD**: INF-01/A – 3 CFU**

Prof. Domenico Rocco (1 CFU) e-mail: domenico.rocco@unicamillus.org
Prof. Franco Arcieri (2 CFU) e-mail: franco.arcieri@unicamillus.org

Teaching module: **Information Processing Systems**
SSD: **INF-05/A - 4 CFU**

Prof. Cantone Marco (2 CFU) e-mail: marco.cantone@unicamillus.org
Prof. Rosa Sicilia (2 CFU) e-mail: rosa.sicilia@unicamillus.org

PREREQUISITES

Knowledge and skills in basic mathematics, statistics and computer science at secondary school level, including arithmetic, algebra, Euclidean geometry, trigonometry and elements of differential and integral calculus. However, teaching does not include propaedeutics.

LEARNING OBJECTIVES

The aim of the integrated Physics and Statistics course (Applied Physics, Medical Statistics and Computer Science) is to provide students with the knowledge of the fundamentals of applied physics, computer science and statistics necessary for their future work. In particular, an understanding of the physical principles underlying medical physics and the functioning of medical instrumentation will be addressed.

At the end of the module, students will know the fundamental concepts of the application of the Scientific Method to the study of biomedical phenomena (choice and measurement of parameters, evaluation of errors), they will be able to describe the physical phenomena of complex systems using appropriate mathematical tools, they will know the scientific basis of medical procedures and the operating principles of equipment commonly used for diagnostics and therapy.
Students should understand the computer tools and concepts that will be useful to them in their future profession in the medical field. It is an essential objective of the Medical Statistics course to learn the knowledge of the essential elements of medical statistics, which include: parameters for descriptive analysis (mean, median, fashion and frequency measures of the distribution of categorical variables), parameters for the analysis of variability (variance, standard deviation and confidence intervals) and elements of inferential statistics (use and interpretation of the most common statistical tests), and regression techniques. Students must be able to: understand the importance of medical statistics in medical research methodology; read a basic biomedical scientific article, understanding its structure and critically evaluating its methods and results; handle a simple database, with particular reference to clinical medicine; carry out descriptive and inferential analysis.

LEARNING OUTCOMES

The expected learning outcomes are consistent with the general provisions of the Bologna Process and the specific provisions of Directive 2005/36 / EC. They are found within the European Qualifications Framework (Dublin descriptors) as follows:

Knowledge and understanding

- To have understood the experimental method and to have acquired rigour in the use and transformations of units of measurement;
- To know and correctly understand the terminology of physics, statistics and computer science. - Know the fundamental principles and laws of physics concerning kinematics, dynamics, electricity and magnetism, vibrations and waves, radiation, nuclear physics and fluids. - Apply these concepts to biological and physiological phenomena in living organisms. - Identify and recognise the physical principles governing the function of specific human organs. - Know the basics of an information system in a healthcare facility. Furthermore, he/she must know how a database is organised and must know some basics of database query languages. He/she must know the security and privacy issues associated with the management of sensitive and non sensitive data such as health data. They must know the problems associated with reading data from electronic instruments, units of measurement, standards, errors.
- Perform a descriptive analysis of a simple database; know and apply frequency and effect measures;
- Demonstrate an understanding of probability and its application;
- Demonstrate ability to handle data and to draw and present quantitative results effectively, using appropriate tables, figures and summaries;
- Evaluate the association between variables;
- Describe the nature of sampling variation and the role of statistical methods in quantifying it, and be able to calculate confidence limits and evaluate assumptions;

- Select and use appropriate statistical methods in the analysis of simple data sets; - Understand the concepts of confounding and effect modification;
- Select and use appropriate statistical methods in the analysis of simple data sets; - Know the basic principles of correlation and linear regression analysis;
- Know introductory elements of multiple linear regression and logistic regression;
- Explain how statistical inference is applied in biomedical research;
- Describe the general principles of power sample size calculation;
- Interpret and evaluate the results of statistical analyses within a scientific publication; Present and discuss the results of statistical analyses in a clear, concise and understandable manner.

EXPECTED LEARNING OUTCOMES

Applying knowledge and understanding

- Apply the principles of physics, computer science and statistics to selected problems and a variable range of situations.
- Use the tools, methodologies, language and conventions of physics, computer science and statistics to test and communicate ideas and explanations.

Communication skills

- Explain arguments in an organized and coherent manner.
- Use scientific language appropriately and in accordance with the topic of discussion.

Making judgements

- Recognise the importance of in-depth knowledge of topics in accordance with appropriate medical education.
- Identify the fundamental role of correct theoretical knowledge of the subject in clinical practice.

SYLLABUS

APPLIED PHYSICS

Introduction, Measurement, Estimating
Measurement and Uncertainty; Significant Figures
Units, Standards, and SI Units
Converting Units
Dimensions and Dimensional Analysis
Vectors and Scalars
Addition of Vectors-Graphical Methods
Subtraction of Vectors and Multiplication of a Vector by a Scalar

Describing Motion: Kinematics

References Frames and Displacement Average Velocity

Instantaneous Velocity
Acceleration
Motion at Constant Acceleration
Kinematics of Uniform Circular Motion
Nonuniform Circular Motion

Dynamics:
Newton's Laws of
Motion Force
Newton's First Law of Motion
Mass
Newton's Second Law of Motion
Newton's Third Law of Motion
Weight-The Force of Gravity;
The Normal Force
Friction
Elasticity and Hooke's Law
Circular Motion
Dynamics of Uniform Circular Motion
Newton's Law of Universal Gravitation
Types of Forces in Nature

Work and Energy
Work Done by a Constant Force
Kinetic Energy
Potential Energy (gravitational potential energy, potential energy of elastic spring)
Conservative and Nonconservative Forces
Mechanical Energy and its Conservation
Problem Solving Using Conservation of Mechanical Energy
Other Forms of Energy: Energy Transformations and the Law of Conservation of Energy
Power

Static Equilibrium
The Conditions for Equilibrium
Applications to Muscles and Joints
Stability and Balance
Elasticity
Stress and Strain
Fracture

Fluids
Phases of Matter
Density
Pressure in Fluids
Pascal's Principle

Buoyancy and Archimedes' Principle
Fluids in Motion;
Flow Rate and the Equation of Continuity
Bernoulli’s Principle
Applications of Bernoulli’s Principle: stenosis, aneurism and TIA Viscosity
Poiseuille’s Equation
High blood pressure Pumps and the Heart

Temperature
Atomic Theory of Matter
Temperature
Thermometers Thermal Equilibrium
Thermal Expansion

Heat
Heat as Energy
Transfer Internal
Energy Specific Heat
Calorimetry
Heat Transfer: Conduction
Heat Transfer: Convection
Heat Transfer: Radiation

The Laws of Thermodynamics
The First Law of Thermodynamics
Human Metabolism and the First Law
Second Law of Thermodynamics-Introduction
Entropy and the Second Law of Thermodynamics
Order to Disorder

Electric Charge and Electric Field
Static Electricity
Insulators and Conductors
Induced Charge
Coulomb's Law
The Electric Field

Electric Potential
Electric Potential Energy
Electric Potential Due to Point Charges
Capacitance Dielectrics

Electric Currents
The Electric Current

Ohm's Law: Resistance and Resistors
Electric Power
Microscopic View of Electric Current
Electrical Conduction in the Human Nervous System

DC Circuits
EMF and Terminal Voltage
Resistors in Series and in Parallel
Kirchhoff's Rules
RC Circuits

Magnetism
Magnets and Magnetic Fields
Electric Current and Magnetic Fields
Ampere's Law

Electromagnetic Induction and Faraday's Law
Induced EMF
Faraday's Law of Induction; Lenz's Law
EMF Induced in a Moving Conductor
Changing Magnetic Flux Produces an Electric Field

Vibrations and Waves
Wave Motion
Types of Waves: Transverse and Longitudinal
Reflection and Transmission of waves
Interference
Principle of Superposition
Standing Waves
Resonance Characteristics of Sound
The Ear and Its Response
Doppler Effect
Applications: Ultrasound and Medical Imaging

Electromagnetic Waves
Production of Electromagnetic Waves
Light as an Electromagnetic Wave and the Electromagnetic
Spectrum Energy in EM Waves

The Wave Nature of Light
The Visible Spectrum and Dispersion

Optical Instruments
The Human Eye; Corrective Lenses
Resolution of the Human Eye and Useful Magnification

Radiation in Healthcare
Electromagnetic radiation
ionizing and non-ionizing radiation
Medical uses for radiation (diagnostics and in therapy)

Ionizing radiation in medicine
X-Ray Medical Imaging
Physical principles and technical aspects of diagnostics x-ray devices
Computed Tomography (CT)
Single Photon Emitting Tomography
(SPECT) C-arm systems and other x-ray equipment

Non-ionizing radiation:
Magnetic Resonance Imaging (MRI)

Radiation protection
Interaction of radiation with cells and tissues
Radiobiology

MEDICAL STATISTICS

Introduction to biostatistics
- Basic Concepts and Definitions
- Measurement and Measurement Scales
- Sampling and Statistical Inference
- Scientific method and design of experiments

Descriptive statistics
- The Ordered Array
- Frequency Tables
- Measures of Central Tendency
- Measures of Dispersion

Basic Probability concepts
- Two Views of Probability: Objective and Subjectiv
- Calculating the Probability of an Event
- Bayes' Theorem, Screening Tests, Sensitivity, Specificity, and Predictive
- Value Positive and Negative

Probability distributions
- Probability Distributions of Discrete Variables
- The Binomial Distribution
- The Poisson Distribution
- Continuous Probability Distributions
- The Normal Distribution
- Normal Distribution Applications

Fundamental concepts of sampling distributions

- Distribution of the Sample Mean
- Distribution of the Difference Between Two Sample Means
- Distribution of the Sample Proportion
- Distribution of the Difference Between Two Sample Proportions

Estimation

- Confidence Interval for a Population Mean
- The t Distribution
- Confidence Interval for the Difference Between Two Population Means
- Confidence Interval for a Population Proportion
- Confidence Interval for the Difference Between Two Population
- Proportions
- Determination of Sample Size for Estimating Means
- Determination of Sample Size for Estimating Proportions
- Confidence Interval for the Variance of a Normally Distributed Population
- Confidence Interval for the Ratio of the Variances of Two Normally Distributed Populations

Hypothesis testing

- Hypothesis Testing: A Single Population Mean
- Hypothesis Testing: The Difference Between Two Population Means
- Paired Comparisons
- Hypothesis Testing: A Single Population Proportion
- Hypothesis Testing: The Difference Between Two Population Proportions
- Hypothesis Testing: A Single Population Variance
- Hypothesis Testing: The Ratio of Two Population Variances
- The Type II Error and the Power of a Test
- Determining Sample Size to Control Type II Errors

Simple linear regression and correlation

- The Regression Model
- The Sample Regression Equation
- Evaluating the Regression Equation
- Using the Regression Equation
- The Correlation Model
- The Correlation Coefficient
- Some Precautions

Multiple regression and correlation

- The Multiple Linear Regression Model
- Obtaining the Multiple Regression Equation
- Evaluating the Multiple Regression Equation
- Using the Multiple Regression Equation
- The Multiple Correlation Model

Regression analysis: some additional techniques

- Qualitative Independent Variables
- Variable Selection Procedures
- Logistic Regression

The Chi-square distribution and the analysis of frequencies

- The Mathematical Properties of the Chi-Square Distribution
- Tests of Goodness-of-Fit
- Tests of Independence
- Tests of Homogeneity
- The Fisher's Exact Test
- Relative Risk, Odds Ratio, and the Mantel–Haenszel Statistic

INFORMATION TECHNOLOGY

- Binary system and information codification, input and output, boolean operators. Computer architecture, CPU, memories:
- Software: operating systems, application software:
- Word processor (Microsoft Word), including bibliography, citations and references: Spreadsheet (Microsoft excel):
- Computer networks, Internet, c-mail. World Wide Web
- Databases, Academic databases and search engines. Public health databases
- Introduction to health information systems. The Italian health information system. Health standards for data acquisition, storing and visualization. The electronic medical record.
- Information security and Privacy in the management of healthcare data.
- Digital devices, sensors and mobile app for precise medicine. Supporting systems for the physicians.
- Analog to digital conversion

INTEGRATION PROCESSING SYSTEMS

1. Introduction (8 hours)
   - Definition of algorithm and information; information processing
   - Basic concepts of hardware and software
   - Overview of programming languages
   - Representation of information; bits and multiples; memory allocation and estimation
   - Binary encoding of numerical data
   - Memory structure and computer architecture; memory hierarchy (primary, cache, secondary)
   - Overview of the implementation of memory and processor

2. Databases (12 hours)
   - Data and information: definitions and distinctions
   - Types of databases: relational, non-relational, cloud-based, and hybrid
   - Core concepts: tables, records, fields, and keys
   - Database Management Systems (DBMS): functions (creation, manipulation, security, and access control); examples of common DBMS; cloud-based DBMS
   - Conceptual data modeling: entities, attributes, and relationships (one-to-one, one-to-many, many-to-many)
   - Entity–Relationship (ER) diagrams; relational model; primary and foreign keys; referential

integrity
- Introduction to SQL: basic commands; conditional query; joins
- Managing data in Excel: the CSV format
- Formulas, expressions, and data visualization through charts in Excel

3. Digital Images (12 hours)
- Overview of the electromagnetic spectrum
- Digital images and color representation
- Image quality parameters and digital image processing techniques (filtering, equalization, point transformations)
- Image compression methods
- The DICOM standard for medical imaging

4. Artificial Intelligence (8 hours)
- Definition and historical overview of Artificial Intelligence (AI)
- The role of data in AI systems
- Supervised, unsupervised, and reinforcement learning: key principles and typical tasks
- Ground truth, confusion matrix, and main performance metrics
- Machine Learning vs. Deep Learning
- Neural networks: artificial neuron, layers, weights, and biases; main applications
- Explainability and limitations of Deep Learning models
- Generative AI: large language models, image, audio, and video generation
- Concepts of creativity and data distribution
- Ethical considerations and risks: hallucinations, bias, privacy, and responsible AI use

TEACHING METHODS

Classroom teaching consists of 50 hours of Applied Physics, 50 hours of Medical Statistics, 30 hours of Computer Science, and 40 hours of Integration and Processing Systems.
The lecturers make use of teaching tools such as PowerPoint presentations containing explanatory diagrams, illustrations, and images. Videos and animations will be employed to integrate the processes described in class.
Interactive lessons are planned, including both individual and group exercises conducted during class. Attendance is mandatory, and students are required to attend at least 67% of the total hours scheduled for the integrated course.

COURSE GRADE DETERMINATION

The examination of the Integrated Teaching of PHYSICS, STATISTICS and INFORMATICS consists of a comprehensive assessment test.
During the written test, the Board of Examiners will assess the student's ability to apply the knowledge and will ensure that the skills are adequate to achieve the objectives. The following will also be assessed: autonomy of judgment, communication skills and learning ability according to the Dublin descriptors.

EVALUATION TEST: Student preparedness will be assessed through a written exam. Some questions may carry different weights (scores) based on their complexity. Questions may be multiple-choice, open-ended, or require problem-solving or exercises. The evaluation for each course will be graded on a scale of thirty. The calculated grade for the integrated course will be the result of a weighted average that takes into account the credit value of each course within the integrated program.

The examination will be assessed overall according to the following criteria:

Not sufficient: significant deficiencies and/or inaccuracies in knowledge and understanding of the topics; limited ability to analyze and synthesize, frequent generalisations.

18-20: barely sufficient knowledge and understanding of the topics with possible imperfections; sufficient ability to analyze, synthesize and make independent judgements.

21-23: routine knowledge and understanding of the topics; correct analysis and synthesis skills with coherent logical argumentation.

24-26: fair knowledge and understanding of the topics; good analytical and synthetic skills with rigorously expressed arguments.

27-29: comprehensive knowledge and understanding of the topics; considerable ability to analyze, synthesize. Good autonomy of judgment.

30-30L: very good knowledge and understanding of topics. Remarkable ability to analyze and synthesize and independent judgment. Arguments expressed in an original manner

OPTIONAL ACTIVITIES

In addition to the teaching activity, the student will be given the opportunity to deepen the topics covered by attending seminars and by suggesting additional readings of articles and book chapters. The topics of the A.D.E. do not constitute examination subjects. The acquisition of the hours allocated to the A.D.E. only takes place with a compulsory attendance of 100%.

READING MATERIALS

APPLIED PHYSICS:

Introduction to Medical Physics, A. Bacchetta, D. Scannicchio, Casa Editrice Ambrosiana (cea) Zanichelli.

The indicated textbook is just a reference. Students are allowed to adopt the book/books of their choice.

INFORMATION TECHNOLOGY: Lesson slides

Hardy, Lynda R, “Health informatics. An interprofessional approach”;

Joos, D. Wolf, R. Nelson, “Introduction to Computers for Healthcare Professionals” seventh edition, 2019, Jones & Bartlett Learning, ISBN 978-1284194708;

Kathleen Mastrian, Dee McGonigle - Informatics for Health Professionals. Jones & Bartlett Learning; 1 edition (April 25, 2016);

Joseph Tan - E-Health Care Information Systems: An Introduction for Students and Professionals. Jossey-Bass Inc Pub; 1 edizione (1 maggio 2012)

The indicated textbooks are just a reference.

MEDICAL STATISTICS: Lesson slides

Daniel, Wayne W, Cross, CL, Biostatistics : a foundation for analysis in the health sciences, 11th edition, Wiley, 2018.

The indicated textbook is just a reference. Students are allowed to adopt the book/books of their choice. Additional material will be provided by the instructor.