SSM
Scuola Superiore Meridionale

Course title:

Scientific Reasoning and Philosophy of Science

Duration [number of hours]**: 24**

PhD Program [MERC/MPS/SPACE]**: MERC/MPHS/SPACE**

Name and Contact details of unit organizer(s):

Name: Franco Garofalo
Affiliation(s): University of Naples Federico II
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Course Description [max 150 words]**:**

The course aims to summarize the philosophical debate initiated in the early 20th century by the logical empiricist movement to understand what science is and what distinguishes scientific from non-scientific claims. The course examines attempts to use logic and probability to define the scientific method and to give scientific reasoning a normative character. In the last part of the course, criticisms of this so-called orthodox view are presented and the current state of the debate about science and the scientific method is discussed. The course is organized in 20 hours of lesson + 4 hours of selected texts readings.

Syllabus [itemized list of course topics]**:**

- Scientific Inquiry
- Formal Logic
- Scientific Method
- The Demarcation Problem
- The Logic of Confirmation
- The Logic of Explanation
- The Casual Conception of Explanation
- Probabilistic Causality
- The Historicist Theories of Scientific Rationality

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

Final oral conversation.

Suggested reading and online resources:

Hans Reichenbach, *The Rise of Scientific Philosophy*, 1957.
Thomas Khun, *The Structure of Scientific Revolutions*, 1962.
Carl Popper, *The Logic of Scientific Discovery*, 1959.
The Stanford Encyclopedia of Philosophy (`https://plato.stanford.edu`)

Course title:

Introduction to Statistical Mechanics

Duration [number of hours]**: 24**

PhD Program [MERC/MPS/SPACE]**: MERC**

Name and Contact details of unit organizer(s):

Name: Giuseppe Petrillo
Affiliation(s): Scuola Superiore Meridionale
Email: g.petrillo@ssmeridionale.it

Course Description [max 150 words]**:**

This course on Statistical Mechanics offering a deep dive into how microscopic behaviors give rise to macroscopic phenomena. Beginning with thermodynamics to establish foundational concepts, it transitions to statistical mechanics through random walks, illustrating how particle dynamics lead to emergent system properties. Starting from Postulates of Statistical Mechanics, bridging microstates with macro observables and revealing the statistical nature of thermodynamic laws, students will explore Canonical and Grand Canonical ensembles, critical for understanding equilibrium systems and predicting behavior under variable conditions. The course culminates with a focus on Critical Phenomena, addressing the complexities of phase transitions beyond classical thermodynamics. This journey aims to equip students with the analytical tools to model and understand physical systems across scales, highlighting the importance of statistical mechanics in explaining and predicting natural phenomena. Through theoretical and practical learning, students will uncover the intricate connection between microscopic interactions and the macroscopic world.

Syllabus [itemized list of course topics]**:**

<u>Overview of thermodynamics</u>
Laws of Thermodynamics, Entropy, Temperature, Thermal equilibrium, Heat Flows, Thermal Capacity, Legendre Transformation, Grand Potential, Variational Principles, Maxwell Relations

<u>Random walk - Introduction to Statistical Mechanics</u>
Non-equilibrium: unbounded random walk, Gaussian Approximation, Equilibrium: random walkers in a box.

<u>The Postulates of Statistical Mechanics</u>
Motion in Γ-Space, Averaging, Liouville Theorem, Ergodic Hypothesis.

<u>Connection with thermodynamics</u>
Degeneracy, Statistical definition of temperature, Entropy, Pressure, chemical potential, etc. in statistical mechanics, Continuous variables.

<u>Canonical ensemble</u>
The ensemble distribution, the partition function, energy distribution, Free energy, First law of thermodynamics, Canonical distribution for classical systems, Energy Equipartition Theorem, Maxwell-Boltzmann Distribution, Ideal gas, Harmonic oscillators, Paramagnetism.

<u>Grand canonical ensemble</u>
Introduction, Particle number distribution, Grand Thermodynamic Potential.

Critical phenomena
Gas-Liquid-Solid transition, Van der Waals theory, Ferromagnetic transition, Critical exponents, Ising Model, Broken Simmetry, Fluctuation-dissipation theorem, Mean fields, Exactly solvable models, Scaling laws and Universality, Renormalization group

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

Final written exam

Suggested reading and online resources:

Notes of the lessons
David Chandler - Introduction to Modern Statistical Mechanics
Kerson Huang - Meccanica Statistica

Course title:

Theory and applications of delay differential equations

Duration [number of hours]**:** **__12_**

PhD Program [MERC/MPHS/SPACE]**:** **__MERC/MPHS____**

Name and Contact details of unit organizer(s):

Prof. John Hogan_______
Affiliation(s): _____University of Bristol______________
Website: https://www.bristol.ac.uk/people/person/John-Hogan-4ff7f0fe-82e7-4ff3-aa4d-ce5c50671bbe/
Email: _____s.j.hogan@bristol.ac.uk_______________

Course Description [max 150 words]**:**

Why is it easier to balance a long stick on the end of your finger, but almost impossible to balance a short one? What happens if red blood cells are late in developing within the body?

The presence of a delay in any system can completely change its behaviour. In this course, we will consider delay differential equations (DDEs). We shall see how even linear DDEs present significant challenges to analysis, both in terms of the problem definition and solution.

The course will contain many examples of DDEs in practice.
By the end of the course, you will know how to classify DDEs, how to set up a DDE system correctly and how to find solutions of certain types of DDE.

You will also discover the critical length of stick that can be balanced on a finger.

Syllabus [itemized list of course topics]**:**

- The importance of initial data
- Differences between DDEs and ordinary differential equations
- The method of steps
- Stability of solutions
- The D-subdivison method, applied to the Hayes equation, damped oscillator equation and Cushing's equation
- The use of the Laplace transform for linear DDEs
- Numerical solution of DDEs

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

Solutions of problems during the course.

Suggested reading and online resources:

Notes: __________
Slides: __________

Suggested books:

There is no suitable textbook. But you could try:

1. T. Erneux (2009) *Applied Delay Differential Equations*. Springer
2. T. Insperger, Gábor Stépán (2011) *Semi-Discretization for Time-Delay Systems*. Springer
3. H. Smith (2011) *An Introduction to Delay Differential Equations with Applications to the Life Sciences*. Springer
4. Y. Kuang (1993) *Delay Differential Equations with Applications in Population Dynamics*. Academic
5. R. Bellman, K. L. Cooke (1963) *Differential-Difference Equations*. Rand Corporation

Some of the material comes directly from scientific papers, which will be fully referenced in the lectures.