SSM
Scuola Superiore Meridionale

Course title:

Physics of matter from the zepto-scale to the macro-scale

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

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

Name and Contact details of unit organizer(s):

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

An introductory "crash-course" in quantum modeling of matter at spatial scales ranging from the elementary-particle "zepto-scale", through nuclei, atoms and molecules, up to macro-scale quantum-based emergent properties of condensed matter. The course will be primarily aimed at students with a non-physics background (e.g., mathematics and engineering students), although we hope physics students may still find it useful.

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

Part 1: Foundations
Lecture 1: The mathematical structure of quantum physics
Lecture 2: A single quantum particle: quantum wells, harmonic oscillator, tunneling
Lecture 3: Atoms, molecules, photons and their interactions
Lecture 4: Solids and electronic bands, entanglement and correlations, bosons and fermions, Fock states

Part 2: Subnuclear and nuclear scales
Lecture 5: Building blocks : leptons and quarks. Symmetries and multiplets.
Lecture 6: Interactions and mediators. S-matrix and Feynman diagrams. Gauge Bosons.
Lecture 7: The Standard Model picture. The role of the Higgs field.
Lecture 8: Nuclear forces and nuclear models. Radioactivity and stability.

Part 3: Macro scales and emergent phenomena
Lecture 9: Emergent phenomena - superconductivity and superfluidity
Lecture 10: Emergent phenomena - superconductivity and superfluidity
Lecture 11: Open quantum systems and Macroscopic quantum dynamics
Lecture 12: Open quantum systems and Macroscopic quantum dynamics

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

For the final exam, the students are asked to prepare an oral presentation on a specific topic related to the course. They will also have to answer to questions which start from the presentation and may touch on the material presented in the course.

1) The presentation can be on any topic related to the course which has not been studied previously by the student (at least not at the same level of depth).

2) The topic of the presentation can be proposed by the students themselves, but it must be approved in advance by one of the instructors. Alternatively, if requested, the instructors can propose a theme to the students.

3) The presentation must be about 30 minutes long. It can be done with the help of slides, in the presence of all three instructors if possible, or at least of two of them.

4) The presentation will be followed by questions by the instructors, which start from the presentation but can range over the entire course content.

Suggested reading and online resources:

Some sections of this open online textbook can be used for background material on part of the course: http://eng-web1.eng.famu.fsu.edu/~dommelen/quantum/style_a/index.html

It is highly recommended that students study the section II.2 (mathematical prerequisites) before the start of the course.

Additional material will include the course slides and, possibly, other textbooks to be defined.