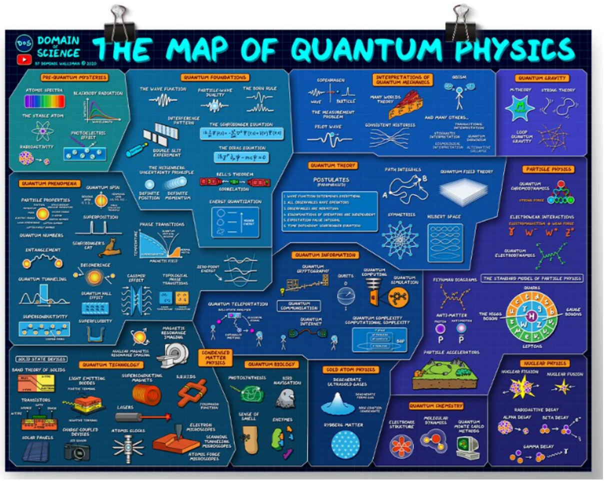

East African Institute for Fundamental Research (EAIFR)

Course:	**Quantum Mechanics II: advanced concepts**
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Course description: The goal of this course is to introduce advanced concepts of modern Quantum Mechanics. This course assumes that the student has gone trough the first part of this course (*Quantum Mechanics I: basic concepts*).

The course is divided in Topics and each topic includes some pages of reference books and papers, hand written notes, video captures of the lectures and, eventually, assignments.

The idea is that the student takes notes during the lecture. These notes can be checked and improved or by using the lecture video *with the help of the hand written notes* and of the references provided. The student is asked to repeat each proof carefully and in detail by taking particular care to the formal aspects of the mathematical derivations.

All references, notes and assignment can be found on the Moodle page.

In the following you can find a detailed list of topics discussed during the lectures.

Part II

1. Symmetry in Quantum Mechanics

1.1 Degeneracies.

1.2 Parity.

1.2.1 Degenerations and parity.

1.2.2 Wave–functions under parity.

1.2.3 Selection rules.

1.3 Lattice translation as a discrete symmetry.

1.4 Time–Reversal (TR).

1.4.1 Wave–functions under TR.

References: Sakurai (1994), pages 248-277
Notes: Hand written L.1 (21 pages)

2. Approximation Methods: non–degenerate and degenerate theory

2.1 Statement of the problem.

2.2 The two–states problem.

2.3 Formal Perturbation Theory: non–degenerate case.

2.3.1 First order.

2.3.2 Second order.

2.3.3 Wave–functions renormalization.

2.3.4 Example: the Perturbed Harmonic oscillator.

2.4 Formal Perturbation Theory: degenerate case.

References: Sakurai (1994), pages 285-302
Notes: Hand written L.2 (19 pages)

3. Approximation Methods: applications

3.1 The linear Stark Effect.

3.2 Hydrogenlike atoms

3.2.1 Spin–Orbit interaction and fine structure.

3.2.2 *Zeeman effect (optional).*

References: Sakurai (1994), pages 302-310
Notes: Hand written L.3 (15 pages)

4. Variational methods and time–dependent phenomena

4.1 Variational methods.

4.2 Time–dependent potentials

4.2.1 The interaction picture.

4.3 The two–states time–dependent problem

4.3.1 General solution.

4.3.2 Resonant case and the Rabi formula.

4.3.3 Non–resonant case.

References: Sakurai (1994), pages 313-325
Notes: Hand written L.4 (22 pages)

5. Hamiltonians with extreme time–dependence

5.1 Sudden approximation.

5.1.1 Preliminary remarks.

5.1.2 Quantum quench of an harmonic oscillator.

5.2 The adiabatic approximation.

5.2.1 Formal definition.

5.2.2 The Berry Phase.

References: Sakurai und Napolitano (2020), pages 327-333
Tong (2017), pages 166-168
Notes: Hand written L.5 (19 pages)

6. Time–dependent perturbation theory

6.1 Time–dependent perturbation theory

6.1.1 Dyson series.

6.1.2 Transition probability.

6.1.3 Constant perturbation.

6.1.4 Harmonic perturbation.

6.2 Interaction with an external classical radiation field

6.2.1 Absorption and stimulated emission.

6.2.2 Dipole approximation.

6.2.3 Photo–electric effect.

References: Sakurai (1994), pages 325-340
Notes: Hand written L.6 (19 pages)

7. Identical particles

7.1 Permutation symmetry.
7.2 The symmetrization postulate.
7.3 Pauli exclusion principle.
7.4 Two–electron system.
7.5 The Helium atom.

References: Sakurai (1994), pages 357-370
Notes: Hand written L.7 (12 pages)

8. Scattering Theory

8.1 The Lippmann–Schwinger equation.
8.2 The Born approximation.

8.2.1 First order.

8.2.2 Higher orders.

8.3 Time–dependent formulation of scattering.
8.4 Connection with time–dependent perturbation theory.

References: Sakurai (1994), pages 379-390
Sakurai (1994), pages 424-429
Notes: Hand written L.8 (19 pages)

9. Quantum Fields

9.1 Second quantization.
9.2 Dynamical variables in second quantization.
9.3 Quantum Fields.
9.4 The Coloumb interaction in second quantization.
9.5 Quantization of the Electro–Magnetic field.

9.5.1 Maxwell equations in free space.

9.5.2 Photons and energy quantization.

9.6 Non–relativistic Quantum Electro Dynamics (QED)

References: Sakurai und Napolitano (2020), pages 454-460
Sakurai und Napolitano (2020), pages 464-468
Notes: Hand written L.9 (21 pages)

10. Relativistic Quantum Mechanics

10.1 Natural units.
10.2 Energy of a free relativistic particle.
10.3 The Klein–Gordon equation.

10.3.1 Relativistic electro–magnetism and the continuity equation.

10.3.2 Covariant formulation.

10.3.3 Quantization of the Klein–Gordon equation.

10.3.4 Particles and anti–particles.

References: Sakurai und Napolitano (2020), pages 478-490
Notes: Hand written L.10 (18 pages)

References

[Sakurai und Napolitano 2020] Sakurai, J J. ; Napolitano, Jim: *Modern quantum mechanics*. 3^{rd}. Cambridge University Press, 2020

[Sakurai 1994] Sakurai, J.J. ; Tuan, S.F. (Hrsg.): *Modern Quantum Mechanics, Revised Edition*. Addison-Wesley, 1994

[Tong 2017] Tong, David: *Topics in Quantum Mechanics*. URL http://www.damtp.cam.ac.uk/user/tong/topicsinqm.html, 2017