

## Quantum World: exam topics

You are allowed to use **your own hand-written notes** at the exam, as long as you can explain the main ideas, the underlying assumptions and their physical implications. You can also include drawings of experimental setups for the paradoxes under 9 and 10.

1. Fundamentals of quantum theory. Parallels between probabilistic formulation of quantum and classical dynamics.
2. Basic differences between quantum and classical theory. Non-commuting observables and incompatibility. Density operators, Gleason's theorem. Pure and mixed state in classical and quantum physics.
3. EPR paradox. Hidden variable theories, basic no-go theorems (von Neumann, Kochen-Specker) and their shortcomings.
4. Simple version of Bell's inequality. Pitowsky theorem and its violation by EPR probabilities. Laboratory notebook argument.
5. Local Markovian determinism, Bell-Clauser-Horne inequalities and their consequences.
6. Composite system, tensor products and partial states. Separability and entanglement, classical versus quantum case.
7. Absence of superluminal signalling, no-communication theorem. Local, quantum and no-signalling correlations.
8. Foundations of consistent histories approach. Relation to sequences of measurements. Double-slit experiment.
9. Wheeler's delayed choice paradox. Delayed choice quantum eraser.
10. Hardy's paradox with particle-anti-particle pairs and with photons.
11. Problem of outcomes: measurement problem, preferred basis problem and issue of emergence of classical behaviour.
12. Environmental decoherence. Simple models: position localisation, q-bit toy model. Apparent collapse, measurement outcomes.
13. Evolution of general quantum systems. CPTP maps, Choi and Choi-Krauss theorems. Purification and Stinepring dilation.
14. Decoherence and branching states. Pointer states. Revisiting fundamental postulates of quantum theory. Repeatability, Hermitian observables and Born's rule.