Aalto University

# Quantum Mechanics
# PHYS-C0252
# lecture starts 10:15

*First lecture on 24.10.2022*

**Lecturers**: Mikko Möttönen and Tapio Ala-Nissilä
**Teaching assistants**: Andras "Marci" Gunyho, Heikki Suominen (and Niko Savola)

# QUANTUM TECHNOLOGY WILL CHANGE THE WORLD (FOR BETTER)

Aalto University

## CHEMISTRY AND PHARMA


AI

## ENERGY

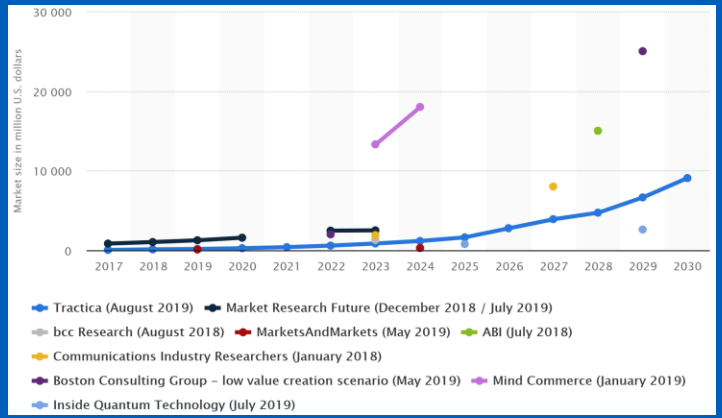
## SUSTAINABILITY

## FINTECH


## CYBER SECURITY

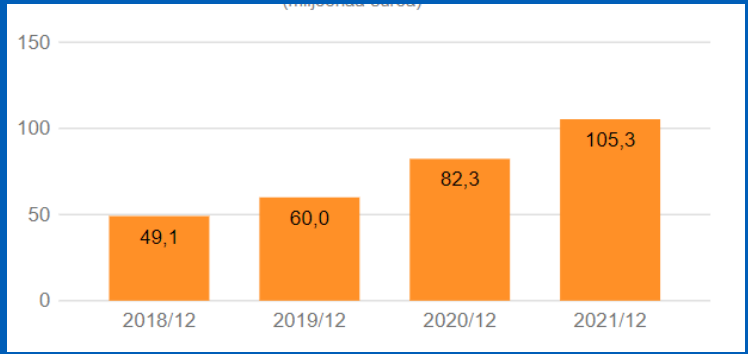
# INDUSTRY RAMPING UP

QUANTUM COMPUTING GLOBAL MARKET PROJECTIONS




https://www.statista.com/statistics/936010/quantum-computing-future-market-outlook-forecast/

ANNUAL REVENUE OF QUANTUM TECH INDUSTRY IN FINLAND (MILLIONS OF EUROS)



# many scientific questions to be answered

# finally job opportunities in quantum

# what an amazing time to study quantum technology!

# Quantum technology – OLD CURRICULUM

## Year 1

### Autumn

- MS-A0111 Diff & int calculus 1
- MS-A0011 Matrix algebra
- CS-A1110 Programming 1
- ELEC-C9420 Intro to quantum tech
- Intro for BSc students
- TU-A1300 Industrial eng manag.
- Language course

### Spring

- MS-A0502 Probability & statistics
- MS-A0211 Diff & int calculus 2
- MS-A0311 Diff & int calculus 3
- CS-A1120 Programming 2
- ELEC-C9430 Electromagnetism
- PH-A0140 Quantum materials/StMa

## Year 2

### Autumn

- MS-C1350 Part diff eqs
- CS-A1140 Data struct & algorith
- PHYS-C0252 Quantum mechanics
- Minor/elective
- Minor/elective
- Minor/elective

### Spring

- ENG-A1003 Numerical Methods
- PHYS-C0256 Thermo & stat mech
- ELEC-C9440 Quantum info
- PHYS-C0254 Quantum circuits
- Aalto course
- Minor/elective

## Year 3

### Autumn

- PHYS-C0258 Quantum labs
- Major optional
- Minor/elective
- Minor/elective
- Minor/elective
- Minor/elective

### Spring

- BSc thesis
- Major optional
- Machine Learning
- Minor/elective
- Minor/elective

# Intended Learning Outcomes (ILOs)

1. Is familiar with the mathematical **structure and postulates of quantum mechanics**
2. Can differentiate between the terms **quantum-mechanical state and wavefunction**
3. Can solve the eigenstates and eigenvalues of the **Schrödinger equation** in simple situations and knows how to generalize the computation to situations where analytical solution is challenging.
4. Can **integrate the quantum evolution** and the expectation values of physical quantities for simple systems.
5. Can apply **creation and annihilation operators** to solve the eigenstates of a one-dimensional harmonic oscillator.
6. Can apply the quantum formalism to model a **qubit and a register of several qubits**.
7. Can predict **measurement** probabilities from a given quantum state.
8. Can apply **perturbation theory** to compute eigensolutions in a situation where analytical solutions is challenging.

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# PEAK AT SYLLABUS

https://mycourses.aalto.fi/course/view.php?id=33562

# Course content, rough

- Hilbert space and Dirac notation
- Operators, eigenvalues and eigenfunctions
- Properties of (Hermitian) operators
- Postulates of quantum mechanics (inc. superposition & meas)
- Expectation values and variance
- Continuous-variable bases: coordinate representation, momentum basis
- Quantization of a physical system
- Schrödinger equation and temporal evolution
- Qubit (two-level system)
- Two-system and entanglement
- Commutator and conserved quantities
- Solving 1D harmonic oscillator using creation and annihilation operators
- Excited states of a 1D harmonic oscillator
- Free particles and plane waves
- Particle in a box
- Particles in different potential wells: infinite and finite wells in 1D
- Scattering and tunneling through barriers
- Bloch's theorem
- Bosons and fermions
- Perturbation theory (non-degenerate)
- Time-dependent perturbation theory
- Time dependence of operators: different pictures
- Adiabatic theorem
- Rabi oscillations

# Particalities

- All in person
  - Future lectures and exercises organized in person (M240&U3/Y308)
  - We aim **not** to have Zoom streaming. Old recording to be in MyCo.
  - Exams are organized in person
- Excercises
  - Deadline for returning solutions every Wednesday night (problems based on the lectures of the previous week)
    - *Exception for last excercise where DL is already on Friday of the publishing week*
  - Problem sets for excercises published by previous Monday
  - Bonus 6 points (one full problem) to the next exam

# Practicalities continue

- Zulip chat to ask for help: https://qmech2022.zulip.aalto.fi/. TAs will try to answer in a reasonable time frame.
- Additions?
- Questions?
- Grading scale last year

| | points | | Final garde |
|---|---|---|---|
| 27 | < | 37 | 5 |
| 24 | < | 27 | 4 |
| 21 | < | 24 | 3 |
| 18 | < | 21 | 2 |
| 15 | < | 18 | 1 |