Relevant Physics Courses: A Summary

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Introduction

The following summary contains a non-exhaustive account of the relevant physics courses taken during my Bachelor's at the Maastricht Science Programme (MSP) at Maastricht University (UM). The summaries will be done as lists of key words and concepts taught in the course. A more in-depth summary can be found by clicking on the title of the course, which will redirect to the course description on the UM website. For the difficulty/level of the course, the MSP ranking will be given. It goes as follows: 1000 level is basic, 2000 level is intermediate and 3000 level is advanced (one course is 4000 because it was offered in a CS Master's programme at UM and I was allowed to take it). This summary does not contain an overview of my Honours Research Programme nor my Bachelor's Thesis Research, as they are not courses. For an overview of these, please read my CV.

Courses

- **Classical Mechanics**, *level 2000*
  Statics and kinematics; Newton's laws; Work and energy; Momentum and collisions; Rotational dynamics; Gravitation.

- **Vibrations and Waves**, *level 2000*
  Simple, damped, driven, coupled harmonic oscillators; Normal modes; Waves; Interference and beats; Standing waves; Wave packets.

- **Optics**, *level 2000*
  Geometric optics; Imaging systems and evaluation of their resolution, field of view and magnification; Limitations and aberrations in optical systems; Wave behaviour of light; Understand and be able to apply polarization, interference and diffraction theory (e.g. non-reflective coatings, Michelson interferometer,...).

- **Electromagnetism**, *level 2000*
  Maxwell's equations; Electrostatics; Electric Fields in Matter; Magnetostatics; Magnetic Fields in Matter.

- **Relativistic Electrodynamics**, *level 3000*
  Maxwell's Equations; Reformulate them in terms of scalar and vector potentials; Gauge freedom; Retarded time; 4-vectors, Lorentz-transformations, Minkowski-spacetime and tensors; Rewriting electrodynamics with 4-vectors; Principle of Least Action and the derivation of the entire classical field theory in covariant form.

- **Thermodynamics and Statistical Physics**, *level 2000*
  Temperature and heat; Thermal properties of matter; The laws of thermodynamics; Entropy enthalpy and free energy; The relation between macroscopic parameters and microscopic dynamics; The statistics of thermodynamic ensembles.

- **Quantum Mechanics I and II**, *level 3000*
  Failings of classical physics; Wave function; Commutation relations of operators; Heisenberg's uncertainty principle; Pauli's exclusion principle; Spin; Calculate the quantized energy states; Square-well potential; Harmonic oscillator; The hydrogen atom in 3D and its orbitals; Quantum tunnelling; Approximation methods such as the variational principle and time (in)dependent perturbation theory; State transitions; Quantum entanglement; Quantum fluctuations.

- **Nuclear and Elementary Particle Physics**, *level 3000*
  Fundamental particles and their properties; How they interact through the three fundamental forces; Quantum Electrodynamics; Weak force; Quantum Chromodynamics; Feynman diagrams; Fermi's golden rule for toy model cross-sections calculations; Symmetry in nature, and its relation to conservation laws.

- **Special Relativity**, *level 3000*
  Discovery of Special Relativity; Relation to electromagnetism; Limited construction of relativis-

tic laws and relationships with Gedankenexperiments; Complete and rigorous construction using Minkowski-geometry; Use of Lagrangian formalism to derive the laws of special-relativistic mechanics.

- **General Relativity**, *level 3000*
  Understand the theory of Special Relativity as a tensor theory; Reformulate gravity as a curvature of spacetime; Understand tensor algebra as a mathematical apparatus; Calculate spacetime curvature in the presence of mass and energy; Calculate motion in curved spacetime; Understand black holes, cosmology, and gravitational waves as specific examples of the theory learned

- **Advanced Mathematical Tools for Physics** , *level 3000*
  Fourier series *(Theorem of Riemann-Lebesque, Dirichlet, Jordan, theorem of Abel-Poison, Cauchy series)*; Fourier integrals *(Banach space, Hilbert space, Schwarz inequality, Parseval, connection to Heisenberg uncertainty relation)*; Bessel and Legendre functions *(Complete sets of orthonormal functions, Euler's constant, Fourier-Bessel series, Hankel transform)*; Laplace transformation *(Complex function theory, s-plane, initial value problems for (partial) differential equations)*; Variational methods *(First order PDEs, second order PDEs, Lagrangian, Euler-Lagrange equation)*; Green's functions *(Solving of potential equations, Dirichlet and von Neumann problems, Wronskian determinant)*

- **Physics Lab I, II and III**, *level 3000*
  The goals of the physics labs are: To acquaint the participants with an overview of the main areas in high level experimental physics; To illustrate the relationship between observation, experiment and hypothesis; To give the participants a better understanding of the laws of physics; To hone the skills required for planning and conducting experimental physics; To develop the skills of experimental design and the impact this has on the outcome.

- **Analysis of Big Data in Physics**, *level 3000*
  Basic concepts of data analysis in physics; Programming; Compare and Evaluate various types of data; Statistical analysis; Proper analysis of errors, correlations and significance; False positives in data; Use of LIGO/Virgo data, CERN/LHCb data and astrophysical datasets.

- **Advanced Electronics**, *level 3000*
  Prerequisite: basics of electronics. The practical will teach: Boolean logic and logic gate applications; Semi-conductors; p-type, n-type; Study and build circuits involving adders, flip-flops, counters and sequential logic; How an electrocardiogram measures the heart's electrical pulses and translates these into an analogue waveform; build an ECG generator and detector and collect measurements using these; use impedance spectroscopy.

- **Image and Signal Processing**, *level 4000*
  Fourier analysis, z-transforms and digital filters; Classical filtering from a linear systems perspective; Wavelet transforms for morphological structures in signals; Principal component analysis; Hilbert-Huang Transform to perform detailed time-frequency analysis of signals; Detection, noise removal, compression, prediction, reconstruction and feature extraction; All practiced and implemented as exercise using Matlab.