

# Applied Data Science M.Sc.: Outline for the Pre-Course Mathematics

*October 20-24 2025, 9:00-12:30, Bernhard Schmitzer, Uni Göttingen*

There will be 2x 90min sessions each morning with 30mins break (=10 sessions). We will not focus on proofs and derivations but on good intuition and practical working knowledge. Questions and feedback of participants on which topics to cover in more detail is explicitly encouraged! Tentative list of topics:

- analysis and calculus (2 sessions)
  - limits
  - 1d: derivative, integral, numerical methods
  - higher dimensions: partial derivatives, gradients, Jacobian (use in chain rule and back propagation), volume integral
  - Taylor expansion
  - simple ODEs (exponential growth, harmonic oscillator, flow in vector field), numerical methods, intuition for SDEs
- linear algebra (3 sessions)
  - matrix-vector multiplication, interpretation
  - linear maps, simple examples: rotations, reflections, projections
  - eigenvalues and -vectors, diagonalization
  - matrix inverses
  - hyperplanes, matrix rank, linear systems
  - Cauchy Schwarz inequality
- probabilities and statistics (3 sessions)
  - 1d: discrete distributions (coin toss, binomial, ...) , normal distribution, general continuous distributions
  - cumulative distribution functions
  - mean/expectation, standard deviation
  - empirical distributions, estimators for mean and standard deviation
  - conditional probability, Bayes' rule, prior and posterior
  - higher dimensions: covariance, correlation
  - hypothesis testing
  - change of variables for probability distributions (in 1d and higher dimensions)
  - Jensen's inequality
- optimization (2 sessions)
  - motivation / examples (model fitting, MLE, MAP, machine learning, engineering, logistics, ...)
  - simple optimality conditions
  - Lagrange multipliers
  - convexity
  - gradient descent
  - Newton method
  - challenges