New Qualifying Exam Syllabus

709

Probability and conditional probability, correlation and independence, random variables, distributions, transformations, expectations, conditional expectations, moment generating functions, useful distributions (binomial, Poisson, negative binomial, normal, gamma, chi-square, t- and F-distributions), exponential and location-scale families, multivariate normal and linear and quadratic forms, convergence (almost surely, in probability, in distribution), law of large numbers, central limit theorem, convergence of transformations, Slutsky theorem and delta method. Sample, population, statistics, sampling distribution, sufficiency, minimal sufficiency, completeness, maximum likelihood, moment method, estimation equations, least squares, weighted least squares, Bayes estimators, bias-variance tradeoff, unbiasedness, UMVUE, information inequality, likelihood ratio tests, evaluation of tests and Neyman Pearson Lemma, uniformly most power tests, duality between tests and confidence sets, pivotal quantities, consistency, asymptotic normality and efficiency, robustness, asymptotic tests based on likelihoods and chi-square tests, concentration inequalities.

710

Minimax optimality, least-favorable priors, Bayes and minimax estimators, empirical Bayes, regularization and James-Stein estimators, super-efficiency, minimax upper and lower bounds, non-parametric regression, kernel density estimation, covering and packing numbers, asymptotic theory of hypothesis testing, hypothesis testing for composite nulls, unbiased tests, uniform laws of large numbers, consistency and asymptotic normality of MLE, asymptotic properties of M-estimators.

849

Linear regression, least squares fit, Gauss-Markov theorem, distributions of quadratic forms, standard model assumptions, computational issues, testing simple and compound hypotheses, prediction, diagnostic tools and model selection (residuals, leverage and influence, Cp, R-square and adjusted R-square, stepwise methods, all possible regressions, leaps and bounds, AIC and BIC), transformations, Box-Cox transformations, multicollinearity, ridge regression, generalized linear models (estimation and testing theory, prediction and model selection, residuals and diagnostics). Model formulation, ANOVA

table, hypothesis testing, diagnostic tools, transformations, multiple comparisons, contrasts, completely randomized designs, block designs, random and mixed effects models, model representations in matrix form, model fitting, testing, and diagnostics, ML and REML.

771

Condition numbers, basics of floating point representations, LU, QR, SVD and Cholesky decompositions with applications to linear models, iterative methods for linear systems (esp. conjugate gradient), convex optimization w/ applications to regularized regression, gradient descent, non-convex optimization (esp. Newton's method), solving nonlinear equations, maximum likelihood, EM algorithm and Gaussian mixture models, bootstrap (non-/semi-/full-parametric), algorithms for generating (pseudo)-random variables from common distributions (e.g., univariate and multivariate normal, chi-square, student's-t, *Fisher scoring,* F, Cauchy, exponential, beta, Dirichlet, Gumbel, categorical, etc.), importance sampling, rejection sampling, Monte Carlo methods, Markov chain fundamentals and simulations, MCMC (esp. Metropolis-Hastings and Gibbs samplers)

Notes

- Any student who fails the exam in 2025 for their first attempt, and seeks to re-take it in 2026, will take the exam under the old format. Students taking the exam for the first time in 2026 must take the exam under the new format/syllabus. From 2027 onward, only the new format will be offered
- If a student has not completed any one of the given core 4 courses in the first year, they will still have covered enough material to score 100% on the qualifying exam, since only the best 3 out of 4 questions are graded
- Exam length will be 4 hours
- Extra proctoring resources may be required to ensure integrity (not using phones or internet)
- While all 4 questions will be graded by the QE committee (to determine which of the 3 are the largest), the full faculty will only observe the 3 largest scores
- The qualifying exam committee can use their discretion on whether to allow computer usage for other questions (if computers should not be used, this needs to be explicitly stated in the question and graded accordingly)

Computing environment

- Exam to be conducted in a computer lab (e.g. Van Hise)
- Students will be provided with R studio only and a list of prescribed packages which will be listed in the exam
- The packages to be used must be explicitly stated in the question
- Internet access will either be blocked (e.g. firewall/virtual machine) or monitored (e.g. tracking usage for each student)
- Any internet use will be considered academic misconduct and the student will automatically fail and further disciplinary action may be taken
- All these ideas will be trialled and tested in 771 this Spring and Spring 2026

Rules/regulations for qualifying exam

Academic integrity on exams is extremely important and taken very seriously. Any violation of these rules will result in an immediate F on the exam and potentially further action depending on the level of academic misconduct.

- All students must seat evenly spaced across the entire computer lab OR have at least one empty seat between them and adjacent students.
- Absolutely no use of any electronic devices other than the computer provided.
- Internet use during the exam is strictly forbidden
- Looking at anybody else' exam is strictly forbidden.

If a student is caught using technology other than the provided computer, the internet, looking at somebody else' exam or violating any other rules, they will automatically score a 0 on the exam and further action may be taken.

In addition, if after completing the exam any member of the qualifying exam committee suspects academic misconduct (i.e. the exam looks suspiciously similar to someone else's exam, an AI-generated solution or any other indications that it is not the student's own work) they may take any of the following actions:

- Give the student an F
- Report the student for academic misconduct
- Remove the student from the program
- Require that the student take a different exam again under stricter supervision