ROYAL STATISTICAL SOCIETY

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Master's (Level 7) Standards in Statistics

In determining the Master's (qualifications framework Level 7) standards for a course in statistics, reference is made to the Graduate, Honours Degree, (Level 6) standards developed by the Royal Statistical Society (RSS). This is to be expected as the RSS standards are based on the QAA Mathematics, Statistics and Operational Research (MSOR) benchmark standards (May 2015); and the QAA standards for Honours Degrees (Level 6) and for Master's Degrees (Level 7) are of a similar structure but with enhanced descriptors for Level 7 (see below for more details).

To recap on the main features of the RSS Level 6 standards:

- These Level 6 standards referenced the knowledge delivered to students and the skills gained by students (i.e. the learning outcomes). Achievement of these standards, together with successful coverage of other criteria (e.g. relating to teaching and assessment, students' outcomes, selection and entry, supporting personal and professional development, resources, quality management) may lead to accreditation of courses by the RSS.

- For the Level 6 standards the knowledge delivered was categorised as
  - Core knowledge (see Appendix 1 of this document)
    - Mathematical techniques
    - Probability
    - Statistical modelling and Inference
  - Specialised or advanced knowledge

- For the Level 6 standards the specific skills gained by students are mapped to the QAA Mathematics, Statistics and Operational Research (MSOR) benchmark standards (May 2015) for honours degrees. See Table 1 below.

The RSS Level 7 standard for a course in statistics is developed for Master's courses that are predominantly 'taught' courses or 'professional/practice' courses; and so it is not applicable to courses that are predominantly 'research' courses.

For the level 7 standard it is expected that the knowledge delivered would include <u>much of</u> the Level 6 core knowledge together with <u>substantially more</u> specialised/advanced knowledge than might be covered at Level 6. This knowledge would need to be delivered in such a way as to enable students to develop and demonstrate skills which map to the QAA MSOR benchmark standards (May 2015) for Master's degrees. See Table 1 below.

Table 1: Mathematics, Statistics and Operational Research (MSOR) benchmark standards for honours degree (Level 6) and for Master's degrees (Level 7).

	MSOR benchmark standards at Level 6	MSOR benchmark standards at Level 7	Additional Level 7 requirement (compared with Level 6)
1.	a reasonable understanding of the basic body of knowledge for the programme of study, normally including calculus and linear algebra	a good understanding of the main body of knowledge for the programme of study including some advanced topics	Enhanced understanding of the body of knowledge. More emphasis on advanced topics.
2.	a reasonable level of skill in calculation and manipulation within this basic body of knowledge and some capability to solve problems formulated within it	a very good level of skill in calculation and manipulation of the material within this body of knowledge, and be capable of solving complex problems formulated within it	Enhanced level of skill in calculation and manipulation. Capability to solve more complex problems.
3.	application of core concepts and principles in well-defined contexts, showing judgement in the selection and application of tools and techniques	application of a range of concepts and principles in loosely defined contexts, showing good judgment in the selection and application of tools and techniques	Application of concepts in more loosely defined contexts.
4.	an understanding of logical arguments, identifying the assumptions made and the conclusions drawn	a high level of capability in developing and evaluating logical arguments	Developing and evaluating logical arguments rather than just understanding such arguments.
5.	a familiarity with the notion of mathematical modelling and a reasonable level of skill in comprehending problems, formulating them mathematically and obtaining solutions by appropriate methods	familiarity with the notion of mathematical modelling, and ability to abstract the essentials of problems, formulating them mathematically, obtaining solutions by appropriate methods and interpreting these solutions	Enhanced ability to abstract the essentials of problems. Ability to interpret solutions.
6.	an ability to communicate straightforward arguments and conclusions reasonably accurately and clearly	confident communication of arguments and effective and accurate conveyance of conclusions	Enhanced communication skills – increased confidence and accuracy.
7.	competent use of appropriate computer technology in mathematics	effective use of appropriate computer technology in mathematics	Effective as opposed to competent use of computer technology.
8.	the ability to manage their own learning and make use of appropriate resources.	the ability to work competently and independently, to be aware of own strengths and to understand when help is needed	Suggestive of more independence in carrying out work.
9.		competence in planning and developing an advanced project themed in mathematics, statistics and operational research.	An additional competency at level 7.

In order to assess achievement of the Level 7 standard, it will be necessary to clearly understand the coverage of the Level 6 core knowledge (see Appendix 1 of this document). That is, it will be necessary to identify:

a) The topics in the Level 6 core knowledge that are included in the course.
b) The topics in the Level 6 core knowledge that are pre-requisites for the course.
c) The topics in the Level 6 core knowledge that are not included in (a) or (b).

For those topics in (b) it will be important to clarify how attainment of the pre-requisite is confirmed for students entering the course. For topics in (c) it will be important to explain how absence of this knowledge does not inhibit students developing understanding of the specialised/advanced knowledge and achievement of the Level 7 learning outcomes.

The substantial specialised/advanced knowledge of the course will need to be detailed (using the same level of detail as given in the Level 6 standard for core knowledge – see Appendix 1) and linked to the specific skills or learning outcomes expected. It is these learning outcomes that should map to the Level 7 MSOR benchmark standards and clearly demonstrate the additional Level 7 requirement when compared with Level 6 (see Table 1, final column).

Table 2 provides generic learning outcomes required to achieve the RSS Level 7 standard. These can be taken as the basis for mapping the course-specific learning outcomes that reflect the areas of advanced or specialised study of the course. (These generic learning outcomes for the RSS Level 7 standard also reflect the terminology of the QAA descriptor for higher education qualification at level 7: master's degree; taken from *The framework for higher education qualifications in England, Wales and Northern Ireland, 2008).* See Appendix 2).

Achievement of the RSS Level 7 standard (in terms of course content and learning outcomes) is a key criterion for RSS accreditation of a Master's course. The full set of criteria can be found in *The RSS Accreditation Scheme – A Guide for Accreditation Partners.*

One of the benefits for students of successful completion of an RSS accredited course is clarity on satisfying the academic requirements for the RSS professional awards of GradStat and CStat. The accreditation statement issued by the RSS will indicate whether there are conditions on whether the accredited course satisfies these academic requirements.

Table 2: Generic learning outcomes for the RSS Level 7 standard mapped to the MSOR benchmark standards for Master's degrees (Level 7).

	MSOR benchmark standards at Level 7	RSS level 7 standards : Learning Outcomes
1.	a good understanding of the main body of knowledge for the programme of study including some advanced topics	A good understanding of • the core Level 6 material (mathematical techniques, probability and statistical inference and modelling) covered in the course (or required as a pre-requisite) or mitigated by additional content, • the substantial specialised/advanced topics which are covered at, or informed by, the forefront of the statistical academic discipline or of current best professional practice.
2.	a very good level of skill in calculation and manipulation of the material within this body of knowledge, and be capable of solving complex problems formulated within it	A very good level of skill in the use of advanced statistical techniques, leading to the capability to solve complex problems; including the ability to: • Formulate problems in statistical terms • Analyse and interpret data using a broad range of advanced techniques; adapting standard techniques as necessary.
3.	application of a range of concepts and principles in loosely defined contexts, showing good judgment in the selection and application of tools and techniques	Ability to: • Use inferential concepts to tackle more open-ended problems, e.g. requiring a choice of model, inference technique, generation of hypotheses to test, revision of a model as a result of a clear lack-of-fit. • show good judgement in the selection and application of appropriate statistical concepts and techniques in loosely defined contexts.
4.	a high level of capability in developing and evaluating logical arguments	Ability to: • Demonstrate the capability to develop and evaluate logical arguments based on the theory and practice of statistical concepts and methods developed on the course. • Appreciate and investigate assumptions underlying statistical modelling and analyses. • Determine and articulate the limitations of statistical analyses and the effects on the conclusions. • Be able to check the sense of conclusions.
5.	familiarity with the notion of mathematical modelling, and ability to abstract the essentials of problems, formulating them mathematically, obtaining solutions by appropriate methods and interpreting these solutions	Ability to: • read descriptions of problems, datasets and background material and abstract the essentials that relate to the main questions of interest; • formulate questions to improve this understanding and/or to clarify issues; • identify the main variable(s) of interest, e.g. the response variable in a regression problem; • consider what kind of probability distribution/model is a sensible choice of working model for the data;

		• understand how the parameters of the model relate to the questions of interest; • appreciate the main modelling assumptions. • fit a statistical model to a set of data, interpreting and reporting on the findings and any assumptions and limitations of the model.
6.	confident communication of arguments and effective and accurate conveyance of conclusions	Ability to: • confidently communicate arguments/issues to others clearly and accurately, in both appropriate written and verbal form • answer subject-matter questions, from both specialist and non-specialist audiences using appropriate language that addresses specific scientific questions of interest. • present data in written and graphical form that conveys a reasoned analysis and conclusions • handle and interpret data sets, assess data relevance and integrity • report on the findings of a statistical analysis through coursework, presentation etc.
7.	effective use of appropriate computer technology in mathematics	Effective use of statistical software • for design (e.g. selection of sample size), • for the management of data (e.g. checking for data errors, creating analysis data sets from raw data sets), and/or • to explore and analyse data. Examples of appropriate packages include: R, STATA, SPSS, SAS
8.	the ability to work competently and independently, to be aware of own strengths and to understand when help is needed	Ability to: • plan work effectively by setting appropriate targets, and monitoring progress against them. • prioritise and organise their time using a range of techniques to deliver high quality work to challenging deadlines. • independently identify a range of sources to improve own learning • reflect on own learning and put strategies in place to improve own learning • work effectively with others to agree realistic objectives, prioritise tasks and identify the resources and timescales needed to complete an activity or project
9.	competence in planning and developing an advanced project themed in mathematics, statistics and operational research.	Competence in planning and developing an extended project demonstrating • comprehensive understanding of advanced/specialist statistical knowledge • critical evaluation of published work and/or current best professional practice • originality in the application of knowledge, for example through the development or novel application of

		methodology; or the analysis of a complex dataset using advanced techniques; or by designing, implementing and reporting an experiment/survey to answer a research question • the ability to present the work in a dissertation.

Areas of advanced/specialised study are typically either application-oriented or technique-oriented. The following list is not intended to be exhaustive, but does include some of the more common specialities offered on Master's courses (Level 7).

Application-oriented	***Technique-oriented***
Actuarial Statistics Ecological Statistics Econometrics Environmental Statistics Financial Statistics Industrial Statistics Medical/Bio Statistics Official Statistics Statistical Genetics	Applied Probability Bayesian Statistics Data Mining Data Science/Big Data Experimental Design Mathematical Statistics Multivariate Analysis Modelling techniques Nonparametric Methods Spatial Processes Statistical Computation Stochastic Processes Survey Methodology Time Series

Appendix 1

Level 6 core knowledge

Mathematical techniques

- Algebra: Permutations and combinations. Partial fractions, solution of linear and quadratic equations, simple inequalities, summation of series with notation, Limits of sequences and functions, geometric series, exponential and logarithmic functions
- Calculus (differential and integral) underpinning the contents below.
- Matrix algebra
- Numerical methods: Iterative solution of equations

Probability

- Basic concepts of set theory and probability: relative frequency, degrees of belief.
- Addition and multiplication rules.
- Conditional probability and associated results: the law of total probability and Bayes theorem.
- Dependence and independence.
- Random variables and probability distributions: univariate, multivariate, marginal, conditional. Summaries of random variables: moments, quantiles etc.
- Important special distributions, e.g. binomial, geometric, Poisson, uniform, exponential, normal, multivariate normal, multinomial, t, chi-squared, F, beta, gamma.
- Expectation, variance and generating functions.
- Sums of IID random variables, weak law of large numbers, central limit theorem.
- Transformation of random variables, the delta method.

Statistical modelling and inference

- Frequentist and Bayesian approaches: principle features of, and the differences between.
- Sample and population, sampling variability.
- The concept of a parametric statistical model.
- Likelihood-based inference.
- Other methods of estimation, e.g. moment-based methods, least squares.
- Point estimation: maximum likelihood estimators in particular.
- Estimation of uncertainty, e.g. interval estimates.
- Observed and expected information, Cramer-Rao lower bound.
- Significance testing and hypothesis testing, including likelihood ratio test. Types of error, power.
- Bayesian methods (including prior and posterior distributions, Bayesian estimates and intervals for parameters and predictions, use of Monte Carlo simulation of the posterior distribution to draw inferences).
- Introduction to designed experiments and surveys (including concepts such as replication, randomisation, blinding, blocking, stratification, clustering, precision, sample sizing).

- Understand the role of asymptotic results.
- Model checking / criticism: informal and formal.
- Prediction, predictive inference.
- Exposure to simple non-parametric methods. Could be as simple as an empirical distribution function or simple sample summaries such as those in ` Summarising and interpreting data' above or some standard non-parametric tests.
- Regression modelling. Knowledge of at least one form of regression modelling with one response and multiple explanatory variables, probably multiple linear regression with IID normal errors.
- The importance of stochastic models (as opposed to deterministic models) in describing many practical situations.
- Awareness of data protection issues

Appendix 2

Descriptor for a higher education qualification at level 7: master's degree (England, Wales and Northern Ireland)

(Taken from *The framework for higher education qualifications in England, Wales and Northern Ireland, 2008.*)

Master's degrees are awarded to students who have demonstrated:

- a systematic understanding of knowledge, and a critical awareness of current problems and/or new insights, much of which is at, or informed by, the forefront of their academic discipline, field of study or area of professional practice
- a comprehensive understanding of techniques applicable to their own research or advanced scholarship
- originality in the application of knowledge, together with a practical understanding of how established techniques of research and enquiry are used to create and interpret knowledge in the discipline
- conceptual understanding that enables the student:
    - to evaluate critically current research and advanced scholarship in the discipline
    - to evaluate methodologies and develop critiques of them and, where appropriate, to propose new hypotheses.

Typically, holders of the qualification will be able to:

- deal with complex issues both systematically and creatively, make sound judgements in the absence of complete data, and communicate their conclusions clearly to specialist and non-specialist audiences
- demonstrate self-direction and originality in tackling and solving problems, and act autonomously in planning and implementing tasks at a professional or equivalent level
- continue to advance their knowledge and understanding, and to develop new skills to a high level.

And holders will have:

- the qualities and transferable skills necessary for employment requiring:
    - the exercise of initiative and personal responsibility
    - decision-making in complex and unpredictable situations
    - the independent learning ability required for continuing professional development.