Examiners' Report: Final Honour School of Mathematics Part B Trinity Term 2013

November 11, 2013

Part I

A. STATISTICS

- **Numbers and percentages in each class.**

  See Table 1.

	Numbers					Percentages %				
	2013	(2012)	(2011)	(2010)	(2009)	2013	(2012)	(2011)	(2010)	(2009)
I	54	(57)	(54)	(55)	(61)	34.34	(34.34)	(36.24)	(35.71)	(36.09)
II.1	78	(79)	(67)	(61)	(76)	49.68	(47.59)	(44.97)	(39.61)	(44.97)
II.2	21	(21)	(19)	(28)	(23)	13.38	(12.65)	(12.75)	(18.18)	(13.61)
III	2	(5)	(7)	(9)	(5)	1.27	(3.01)	(4.70)	(5.84)	(2.96)
P	2	(3)	(2)	(0)	(3)	1.27	(1.81)	(1.34)	(0)	(1.78)
F	0	0	(0)	(1)	(1)	0	(0)	(0)	(0.65)	(0.59)
Honours (unclassified)	0	(1)	(0)	(0)	(0)	0	(0.6)	(0)	(0)	(0)
Total	157	(166)	(149)	(154)	(169)	100	(100)	(100)	(100)	(100)

Table 1: Numbers and percentages in each class

- **Numbers of vivas and effects of vivas on classes of result.**

  As in previous years there were no vivas conducted for the FHS of Mathematics Part B.

- **Marking of scripts.**

  The following were double marked: whole unit BE Extended Essays, BSP projects, and coursework submitted for the History of Mathematics course, the Mathematics Education course and the Undergraduate Ambassadors Scheme.

  The remaining scripts were all single marked according to a pre-agreed marking scheme which was strictly adhered to. For details of the extensive checking process, see Part II, Section A.

- **Numbers taking each paper.**

  See Table 5 on page 12.

B. New examining methods and procedures

There were no new examining methods or procedures this year.

C. Changes in examining methods and procedures currently under discussion or contemplated for the future

None.

D. Notice of examination conventions for candidates

The first Notice to Candidates was issued on 19 February 2013 and the second notice on 29 April 2013. These notices can be found at https://www.maths.ox.ac.uk/notices/undergrad/2012-13/part-b, and contain details of the examinations and assessments.

The Examination Conventions for 2013 examinations are on-line at https://www.maths.ox.ac.uk/notices/undergrad.

Part II

A. General Comments on the Examination

The examiners would like to convey their grateful thanks for their help and cooperation to all those who assisted with this year's examination, either as assessors or in an administrative capacity. However we, and the Chairman in particular, do wish to single out for special mention Vicky Archibald for providing excellent administrative support throughout and Charlotte Turner-Smith for her help and support whenever this was needed. We are extremely grateful to Waldemar Schlackow for the excellent work he has done in maintaining and running the database, assisting the examiners in the operation of the scaling algorithm, and in generating output data as requested by the examiners. We are also grateful to Margaret Sloper for her assistance during the logging in and checking of scripts and to Helen Lowe for her help in running the database. We should also like to thank the organisers of the Structured Projects option, Drs Stedall and Wilkins, for their constructive participation in discussions on the assessment of BSP.

In addition the internal examiners would like to express their gratitude to Professor Lister and Professor Thomas for carrying out their duties as external examiners in a constructive and supportive way during the year, and for their valuable input at the final examiners' meeting.

Timetable

Examinations began on Monday 29 May and finished on Thursday 13 June.

Medical certificates and other special circumstances

The examiners considered medical certificates relating to the Part B examination and also certificates passed on by the examiners in Part A 2012. All candidates with certain conditions (such as dyslexia, dyspraxia, etc) were given special consideration in the conditions and/or time allowed for their papers, as agreed by the Proctors. Each such paper was clearly labelled to assist the assessors and examiners in awarding fair marks. Details of cases in which special consideration was required are given in Sections F.2 and F.3.

Setting and checking of papers and marks processing

The protocols set out in Section 4.2 of the Examination Conventions for Part B were followed. Requests to course lecturers to act as assessors, and to act as checkers of the questions of fellow lecturers, were sent out early in Michaelmas Term, with instructions on the setting and checking process, including a web link to the Examination Conventions. The questions were initially set by the course lecturer, in almost all cases with the lecturer of the corresponding half unit involved as checkers before the first drafts of the questions were presented to the examiners. Significant difficulties were caused this year to the examiners and to the staff in the Academic Office by the failure by a number of assessors to meet the stipulated deadlines and/or to follow carefully the instructions provided.

The internal examiners met at the beginning of Hilary Term to consider those draft papers on Michaelmas Term courses which had been submitted in time; consideration of the remaining papers had to be deferred. Where necessary, corrections, and any proposed changes, were agreed with the setters. The revised draft papers were then sent to the external examiners. Feedback from external examiners was given to examiners and to the relevant assessor for response. The internal examiners at their meeting in mid Hilary Term considered the external examiners' comments and the assessor responses, making further changes as necessary before finalising the questions. The process was repeated for the Hilary Term courses, but necessarily with a much tighter schedule. Camera ready copy of each paper was required to be signed off by the assessor. CRC for all papers was submitted, on schedule but with no time to spare, to the Examination Schools by Monday week 1 of Trinity Term.

As noted in the report on Part B 2012, the checking and signing off processes last year had not proved sufficiently robust to prevent significant errors being present in one paper—a rare but highly regrettable occurrence. Following recommendations made by the 2012 examiners, the instructions to setters and checkers were amplified to make explicit some points of good practice previously left implicit. This, and the vigilance of the examiners, ensured that almost all papers were entirely free of errors, and that only a very few errors, each very small, came to light when the papers were sat.

Except by special arrangement, examination scripts were delivered to the Mathematical Institute by the Examination Schools, and markers collected their scripts from the Mathematical Institute. Marking, marks processing and checking were carried out according to well-established procedures.

Assessors had a short time period to return the marks on standardised mark sheets. A check-sum is also carried out to ensure that marks entered into the database are correctly read and transposed from the mark sheets.

All scripts and completed mark sheets were returned, if not by the agreed due dates, then at least in time for the script-checking process. A team of graduate checkers under the supervision of Vicky Archibald sorted all the scripts for each paper for which the Mathematics Part B examiners have sole responsibility, carefully cross checking against the mark scheme to spot any unmarked questions or parts of questions, addition errors or wrongly recorded marks. Also sub-totals for each part were checked against the mark scheme, noting correct addition. In this way, errors were corrected with each change independently verified and signed off by one of the examiners, who were present throughout the process. We commend this year's markers for adhering strictly to the marking instructions and for almost invariably performing internal additions correctly. Consequently there were very few queries which had to be referred to the marker for resolution.

Determination of University Standardised Marks

The examiners followed established practice in determining the University standardised marks (USMs) reported to candidates. The procedures adopted are outlined below. In carrying out the process, the examiners took note of

- the Examiners' Report on the 2012 Part B examination, and in particular recommendations made by last year's examiners, and the Examiners' Report on the 2012 Part A examination, in which the 2013 Part B cohort were awarded their USMs for Part A;
- a document issued by the Mathematics Teaching Committee giving broad guidelines on the proportion of candidates that might be expected in each class, based on the class percentages over the last five years, together with recent historic data for Part A.
- reports solicited from the assessors on the standard of the work presented for the questions they had marked. Assessors were also asked to estimate where they considered class borderlines might fall for the sets of scripts they had marked. A number were unable to provide such estimates, because they did not have enough data to comment

or because they felt they had insufficient experience of examining standards in Oxford.

We first outline the principles of the calibration method used to derive USMs from raw marks and then give details of this year's process.

The Department's algorithm to assign USMs in Part B was used in the same way as last year for each half unit assessed by means of a traditional written examination. Papers for which USMs are directly assigned by the markers or provided by another board of examiners are excluded from consideration; these papers included all those on whole units. Calibration uses data on the Part A performances of candidates in Mathematics and Mathematics & Statistics (Mathematics & Computer Science and Mathematics & Philosophy students are excluded at this stage). Working with the data for this population, numbers N_1, N_2 and N_3 are first computed for each paper: N_1, N_2 and N_3 are, respectively, the number of candidates taking the paper who achieved in Part A average USMs in the ranges $[70, 100]$, $[60, 69]$ and $[0, 59]$, respectively.

The algorithm converts raw marks to USMs for each paper separately (in each case, the raw marks are initially out of 50, but are scaled to marks out of 100). For each paper, the algorithm sets up a map $R \to U$ (R = raw, U = USM) which is piecewise linear. The graph of the map consists of four line segments: by default these join the points $(100, 100)$, $P_1 = (C_1, 72)$, $P_2 = (C_2, 57)$, $P_3 = (C_3, 37)$, and $(0, 0)$. The values of C_1 and C_2 are set by the requirement that the proportion of I and II.1 candidates in Part A, as given by N_1 and N_2, is the same as the I and II.1 proportion of USMs achieved on the paper. The value of C_3 is set by the requirement that P2P3 continued would intersect the U axis at $U_0 = 10$. Here the default choice of *corners* is given by U-values of 72, 57 and 37 to avoid distorting nonlinearity at the class borderlines.

The results of the algorithm with the default settings of the parameters provide the starting point for the determination of USMs. The examiners have scope to make changes, usually by adjusting the position of the corner points P_1, P_2, P_3 by hand, so as to alter the map raw $\to$ USM, to remedy any perceived unfairness introduced by the algorithm. They also have the option to introduce additional corners. For a well-set paper taken by a large number of candidates, the algorithm yields a piecewise linear map which is close to linear, usually with somewhat steeper first and last segments. If the paper is too easy or too difficult, or is taken by only a few candidates, then the algorithm can yield anomalous results—very steep first or last sections, for instance, so that a small difference in raw mark can lead to a relatively large difference in USMs. For papers with small numbers of candidates, moderation may be carried out by hand rather than by applying the algorithm.

Following customary practice, a preliminary, non-plenary, meeting of examiners was held two days ahead of the first plenary examiners' meeting to assess the results produced by the algorithm and to make changes if necessary, so that the starting point for the first plenary meeting was a set of USM maps yielding a tentative class list with class percentages roughly in line with historic data. For the majority of papers this year's data gave rise to scaling maps which, after small adjustments only, were quite close to linear, and without very steep end segments. For two papers in particular, quite significant changes needed to be made to the default scaling maps; raw marks which were uniformly rather high contributed to the difficulties in scaling these papers appropriately.

The USM marks for BSP (Structured Projects) were also reviewed at the preliminary meeting; Dr Stedall, representing the BSP organisers, was invited to take part in this discussion. The examiners this year (and last year too) had concerns that marks awarded for the presentation and peer review components might be resulting in USMs which were, by comparison with USMs on traditional examinations and marks on the written report on the project, slightly too high. The database was used to inform how the presentation marks might be adjusted in a way that would be proportionate and still reflect candidates' good performance on the BSP tasks. This worked well, and the BSP USMs were adjusted accordingly. We stress that the action taken did not amount to bringing BSP within the algorithmic scaling procedure.

The first plenary examiners' meeting began with a brief overview of the methodology and of this year's data. For each paper, the data and provisional scaling were scrutinised in turn. The Statistics external examiner was present for discussion of papers involving candidates in Mathematics & Statistics. The full session was then adjourned to allow the external examiners to look at scripts. The examiners reconvened, with all Mathematics & Statistics examiners present, to confirm the scaling maps. The Mathematics external examiners expressed concern that the classification stemming from the provisional scaling maps was over-generous at the II.1/II.2 borderline. By mutual agreement, the scaling maps were reviewed and the default U-coordinate at 57 was adjusted downwards in certain cases. Table 2 on page 9 gives the final positions of the corners of the piecewise linear maps used to determine USMs.

At their final meeting on the following morning, the Mathematics examiners reviewed the positions of all borderlines for their cohort. For candidates very close to the proposed borderlines, marks profiles and particular scripts were reviewed before the class list was finalised.

In accordance with the agreement between the Mathematics Department and the Computer Science Department, the final USM maps were passed to the examiners in Mathematics & Computer Science. USM marks for Mathematics papers of candidates in Mathematics & Philosophy were calculated using the same final maps and passed to the examiners for that School.

Table 2: Position of corners of the piecewise linear maps

Paper	P_1	P_2	P_3	N_1	N_2	N_3
B1a	(17.58, 37)	(30.6, 55)	(41, 70)	13	18	7
B1b	(11.67, 37)	(20.3, 55)	(33.8, 72)	19	23	8
B2a	(12, 37)	(23, 55)	(35, 72)	19	13	1
B2b	(12.47, 37)	(21.7, 55)	(38.2, 72)	19	13	1
B3a	(18.09, 37)	(31.5, 55)	(39, 72)	7	3	1
B3b	(14.82, 37)	(25.8, 55)	(35, 72)	9	4	1
B3.1a	(13.21, 37)	(23, 55)	(38, 72)	13	7	2
B4a	(11.72, 37)	(20.4, 55)	(38.4, 72)	21	15	3
B4b	(10.91, 37)	(19, 55)	(34, 72)	18	8	3
B5a	(14.76, 37)	(25.7, 55)	(41, 70)	23	45	18
B5b	(14.02, 37)	(24.4, 55)	(40, 70)	23	38	16
B5.1a				2	0	0
B6a	(21.20, 37)	(36.9, 55)	(45, 70)	15	31	13
B6b	(13.44, 37)	(23.4, 55)	(41.4, 72)	15	30	11
B7.1a	(11.49, 37)	(20, 55)	(35, 72)	17	27	11
B7.2b	(20.62, 37)	(34, 55)	(45, 70)	16	19	8
B8a	(14.94, 37)	(26, 55)	(41, 72)	18	39	17
B8b	(16.26, 37)	(28.3, 55)	(41.8, 72)	9	14	7
B9a	(14.71, 37)	(25.6, 55)	(37.6, 72)	28	17	5
B9b	(13.73, 37)	(23.9, 55)	(34.4, 72)	23	12	4
B10a	(12.47, 37)	(21.7, 57)	(37, 72)	9	19	3
B10b	(11.32, 37)	(19.7, 57)	(36.2, 72)	16	43	14
B11a	(13.27, 37)	(23.1, 57)	(40, 72)	6	24	6
B21a	(15.68, 37)	(27.3, 57)	(38.5, 72)	9	18	7
B21b	(15.74, 37)	(27.4, 57)	(43, 72)	5	16	4
B22a	(12.93, 37)	(22.5, 57)	(40.5, 71)	3	8	3
OBS1	(34.58, 37)	(60.2, 57)	(78, 72)	5	18	6
OBS2a	(18.33, 37)	(29, 57)	(36.5, 70)	2	11	3
OBS3a	(16.26, 37)	(27, 57)	(40.3, 72)	16	42	18
OBS3b	(12, 37)	(19.1, 57)	(36, 72)	7	15	5
OBS4a	(12.47, 37)	(21.7, 57)	(36, 72)	15	37	10
OBS4b	(17.06, 37)	(27, 57)	(44, 72)	12	35	9

Table 3 gives the rank of candidates and the number and percentage of candidates attaining this or a greater (weighted) average USM.

Table 3: Rank and percentage of candidates with this or greater overall USMs

Av USM	Rank	Candidates with this USM and above	%
98	1	1	0.64
89	2	2	1.27
88	3	3	1.91
87	4	4	2.55
86	5	7	4.46
85	8	8	5.1
84	9	11	7.01
83	12	12	7.64
82	13	14	8.92
81	15	16	10.19
80	17	17	10.83
79	18	18	11.46
78	19	21	13.38
76	22	25	15.92
75	26	29	18.47
74	30	33	21.02
73	34	40	25.48
72	41	45	28.66
71	46	50	31.85
70	51	54	34.39
69	54	59	37.58
68	59	68	43.31
67	68	77	49.04
66	78	85	54.14
65	86	95	60.51
64	96	102	64.97
63	103	107	68.15
62	108	120	76.43
61	121	126	80.25
60	126	132	84.08
59	133	138	87.9
58	139	139	88.54
57	140	142	90.45
56	143	145	92.36
55	146	147	93.63
54	148	149	94.9
52	150	151	96.18
51	152	153	97.45
45	154	154	98.09
44	155	155	98.73
38	156	156	99.36
35	157	157	100

B. Equal opportunities issues and breakdown of the results by gender

Table 4 shows the performances of candidates broken down by gender.

Table 4: Breakdown of results by gender

Class	Total		Male		Female	
	Number	%	Number	%	Number	%
I	54	34.34	46	40.35	8	18.18
II.1	78	49.68	52	45.61	26	59.09
II.2	21	13.38	13	11.4	8	18.18
III	2	1.46	1	0.88	1	I2.27
P	2	1.46	2	1.75	0	0
Total	157	100	114	100	43	100

C. Detailed numbers on candidates' performance in each part of the examination

The number of candidates taking each paper is shown in Table 5.

Table 5: Numbers taking each paper

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
B1a	38	37.26	5.81	65.95	10.5
B1b	49	31.33	8.55	69.71	13.07
B2a	33	33.39	8.24	70.82	13.31
B2b	30	36.53	7.31	73.47	11.08
B3a	11	39.18	7.52	74	16.07
B3b	14	36	9.05	74.07	16.74
B3.1a	22	37.05	8.29	74.55	13.93
B4a	39	34.23	7.76	69.38	10.98
B4b	29	32.69	8.57	72.1	12.27
B5a	85	34.44	8.4	64.25	12.29
B5b	78	33.73	8.5	64.35	13.1
B5.1a	2				
B6a	58	41.55	6.24	67.59	14.19
B6b	54	33.67	9	65.54	13.68
B7.1a	56	28.36	8.49	64.57	12.43
B7.2b	43	42.67	5.28	71.37	13.13
B8a	72	32.88	7.87	62.99	11.6
B8b	29	34.62	7.54	63.72	11.83
B9a	50	36.54	5.83	71.96	10.3
B9b	39	33.49	6.34	70.74	10.9
B10a	16	32.5	8.45	64.88	8.79
B10b	35	27.89	10.26	62.83	13.62
B11a	32	29.38	8.24	63.94	11.23
B11b	50	31.82	7.31	66.62	10.63
B21a	29	32.45	8.6	62.93	11.73
B21b	18	33.56	9.47	66.06	11.83
B22a	15	28.87	8.48	62.13	15.1
OBS1	2				
OBS2a	2				
OBS3a/B12a	35	28.43	8.23	64.86	12.23
OBS3b	7	26.57	16.98	57.29	27.44
OBS4a	32	28.62	11.02	61.81	16.95
OBS4b	22	27.09	6.91	63.95	9.61
C7.1b	19	-	-	67.16	12.38
BE	6	-	-	68.83	7.17
O1	6	-	-	67.33	4.76
BSP	19	-	-	67.53	5.72
N1a	11	-	-	67.36	4.67
N1b	7	-	-	66	2
102	2				
122	2				

Individual question statistics for Mathematics candidates are shown below for those papers offered by no fewer than six candidates.

Paper B1a: Logic

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	22.5	22.5	2.45	38	0
Q2	14.45	14.45	4.26	33	0
Q3	16.8	16.8	2.17	5	0

Paper B1b: Set Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	12.97	12.94	5.26	34	2
Q2	16.44	16.63	4.81	35	1
Q3	17.69	17.69	3.59	29	0

Paper B2a: Introduction to Representation Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.37	16.37	4.56	27	0
Q2	15.95	16.43	5.43	21	1
Q3	17.31	17.5	4.06	18	1

Paper B2b: Group Theory and an Introduction to Character Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.11	18.06	4.9	16	2
Q2	18.14	18.14	3.47	22	0
Q3	17.74	18.55	6.58	22	1

Paper B3a: Geometry of Surfaces

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	21.64	21.64	3.29	11	0
Q2	18.43	17.5	3.6	6	1
Q3	17.6	17.6	6.69	5	0

Paper B3b: Algebraic Curves

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	19.58	19.58	4.85	12	0
Q2	17.08	18.17	6.63	12	1
Q3	12.75	12.75	8.65	4	0

Paper B3.1a: Topology and Groups

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	18.38	18.38	3.96	16	0
Q2	19.16	19.16	5.39	19	0
Q3	17.44	17.44	5.68	9	0

Paper B4a: Banach Spaces

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.25	16.54	4.96	31	1
Q2	16.25	16.26	4.1	27	1
Q3	18.38	19.15	4.78	20	1

Paper B4b: Hilbert Spaces

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	13.67	17	8	7	2
Q2	15.75	15.75	5.17	24	0
Q3	16.70	16.70	4.97	27	0

Paper B5a: Techniques of Applied Mathematics

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.57	16.57	3.83	84	0
Q2	18	18	6.03	81	0
Q3	8.67	15.4	7.46	5	7

Paper B5b: Applied PDEs

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	15.26	16.17	6.80	46	4
Q2	12.24	13.78	6.01	36	10
Q3	18.10	18.80	4.31	74	3

Paper B6a: Viscous Flow

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	21.23	21.23	3.55	56	0
Q2	19.38	20	4.56	50	2
Q3	22.1	22.1	5.09	10	0

Paper B6b: Waves and Compressible Flow

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	18.02	18.02	3.84	47	0
Q2	14.41	14.68	5.38	31	1
Q3	15.97	17.79	6.81	29	4

Paper B7.1a: Quantum Mechanics

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.35	17.35	3.89	43	0
Q2	11.64	12.35	4.85	48	5
Q3	11.21	11.86	6.07	21	3

Paper B7.2b: Special Relativity and Electromagnetism

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	21.22	21.17	2.62	36	1
Q2	22.47	22.47	3.62	36	0
Q3	17.61	18.86	4.94	14	0

Paper B8a: Mathematical Ecology and Biology

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.65	16.65	4.40	65	0
Q2	13.96	15.18	5.84	22	3
Q3	16.68	16.68	4.27	57	0

Paper B8b: Nonlinear Systems

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	15.13	15.64	4.98	22	1
Q2	18.54	19.19	5.53	27	1
Q3	14.5	15.78	5.82	9	3

Paper B9a: Galois Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.27	17.27	3.49	49	0
Q2	19.24	19.24	3.65	49	0
Q3	17	19	5.29	2	1

Paper B9b: Algebraic Number Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16	16.2	4.91	15	1
Q2	16.84	17.08	3.41	37	1
Q3	16.04	16.58	4.45	26	1

Paper B10a: Martingales through Measure Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.38	16.38	3.93	16	0
Q2	15.77	15.77	6.10	13	0
Q3	14.25	17.67	8.02	3	1

Paper B10b: Mathematical Models of Financial Derivatives

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	12.85	13.94	7.49	18	2
Q2	12	13.59	7.23	22	3
Q3	14.2	14.2	4.63	30	0

Paper B11a: Communication Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	15.52	15.88	3.93	26	1
Q2	13.3	13.3	5.69	30	0
Q3	16	16	5.13	8	0

Paper B11b: Graph Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	15.83	16.25	3.92	44	2
Q2	15.27	15.27	4.08	30	0
Q3	15.43	16.08	5.51	26	2

Paper B21a: Numerical Solution of Differential Equations I

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.17	17.17	5.20	29	0
Q2	15.29	15.29	5.03	24	0
Q3	13.33	15.2	6.12	5	1

Paper B21b: Numerical Solution of Differential Equations II

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	19.54	19.54	5.22	13	0
Q2	15.71	15.71	5.25	17	0
Q3	12	13.83	5.23	6	1

Paper B22a: Integer Programming

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	13.69	13.69	4.94	13	0
Q2	14.67	17.6	9.22	5	1
Q3	13.92	13.92	4.27	12	0

Paper B12a/OBS3a: Applied Probability

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	12.5	14.5	14.85	28	2
Q2	14.8	14.8	4.37	35	0
Q3	16	16	3.96	7	0

Paper OBS3b: Statistical Lifetime-Models

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
%hline Q1	10.4	10.4	8.20	5	0
Q2	15.25	15.25	10.63	4	0
Q3	18.25	18.25	3.5	4	0

Paper OBS4a: Actuarial Science I

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	15.55	15.55	4.88	31	0
Q2	10.32	10.92	7.06	26	2
Q3	21.43	21.43	4.79	7	0

Paper OBS4b: Actuarial Science II

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	12.71	13.25	5.46	20	1
Q2	7.8	12.2	5.37	5	5
Q3	14.21	14.21	3.74	19	0

D. Recommendations for Next Year's Examiners and the Mathematics Teaching Committee

We first discuss issues directly concerned with the way in which candidates are assessed, across the whole examination and in two particular options. Our remaining comments concern the running of the examination process and the part played in this by the assessors.

1. Class boundaries and class descriptors

Many of this year's papers worked successfully, with some interesting and carefully constructed questions which discriminated effectively at all levels of ability. Where papers, or individual questions, were less successful this seemed to be because too much material which had been seen before was included, or too high a proportion of such material. Scaling of papers on which there were two popular questions with average raw marks in excess of 20 were particularly difficult to scale, with the default scaling maps needing substantial amendment and the final scaling not wholly satisfactory.

At the upper end, most papers worked well for ranking the stronger candidates. We are pleased to note observations from a number of assessors that final parts of particular questions were challenging and that there was not a surfeit of raw marks close to 50 (out of 50). (Where this does occur on any paper, a fair translation to USMs is hard to achieve because the top segment of the scaling map is steep.) At the other end of the scale, the raw marks of the bottom 10% of candidates fell away sharply, and the lower borderlines were straightforward to settle.

However we did encounter difficulties in respect of the II.1/II.2 borderline. Around this level, the candidates' performance called into question whether they had demonstrated that they fulfilled the requirements for an upper second, as specified by the class descriptor:

Upper Second Class: the candidate shows good or very good skills in reasoning, deductive logic and problem-solving. He/she demonstrates a good or very good knowledge of much of the material.

Here it is fulfilment of the first condition that exercises us rather than the second. The corresponding descriptor for a II.2 reads:

Lower Second Class: the candidate shows adequate basic skills in reasoning, deductive logic and problem-solving. He/she demonstrates a sound knowledge of much of the material.

A high proportion of candidates in the second and third quartiles were able to achieve 15 marks out of 25 on almost all their answers. However, very many such candidates scored almost all their marks on material which came straight from lecture notes or problem sheets. Often, either they did not reach parts of questions which required problem-solving skills in unfamiliar situations or, in some cases, they crashed badly on such parts. We note that a number of assessors comment in their reports on questions which proved to be over-long or on which candidates wrote more than necessary. When a question is overloaded with bookwork which as a consequence attracts not many marks, small but significant errors and omissions deither go unpenalised or incur a disproportionate penalty. For a given number of marks, a small volume of material, strictly marked, may test understanding more effectively than a larger volume not marked so strictly.

We make the following RECOMMENDATIONS. Taken in conjunction, these seek to enable examiners better to measure students' attainment against the class descriptors reproduced above.

(a) The pure bookwork part of each question should kept short enough for an average candidate to be able to cover it in about 15–20 minutes, so leaving time for the candidate to make a serious attempt at the remainder of the question.

(b) Setters should be strongly encouraged to incorporate into their questions tests of understanding of the basic bookwork, through simple problem-solving tasks or requests for small pieces of supplementary information not given verbatim in course notes.

(Item (b) does not refer to 'tails' of questions, which should continue to contain unfamiliar material and be designed to discriminate between the strongest candidates.)

In part, but only in part, implementation of these recommendations would require amendments to the checklist for setters and checkers included in the Examination Conventions. We hope that, insofar as this is feasible within the formal procedural framework, changes to the style of questions will be made for the 2014 examination. At the least, the *volume* of bookwork tested in the early parts of questions could be constrained, without altering the credit available for such parts, and more stringent marking of this bookwork encouraged.

Part B from 2014/5 onwards will follow on from the new structure of the first and second year courses, and there will inevitably be changes to Part B as a result of syllabus changes lower down. We suggest that it would be appropriate, ahead of these changes, for a review of guidelines for assessment in Part B to take place in the coming academic year. Such a review should be against the background of the factors noted below, and with particular reference to discriminating between candidates who deserve a II.1 classification and those who should be awarded a II.2. There might need, also, to be some reassessment of how well the scaling algorithm currently operates, or would operate if the recommendations above are adopted in full.

The following summary of changes since 2009, and their consequences, is largely based on information to be found in published Examiners' Reports and minutes of committees, in particular the Mathematics Teaching Committee and the Joint Consultative Committee with Undergraduates. The more subjective interpretations come from tutors' perceptions of student attitudes, as revealed through tutorials, intercollegiate classes and revision consultation sessions. We believe these interpretations to be well founded.

For many years there were concerns, expressed by external examiners in particular, that weaker candidates were not showing knowledge of an adequate spread of material and that the scripts of such candidates were too slight to allow their level of attainment to be reliably classified. A number of changes were made which assisted in addressing this issue in various ways: amending the checklist for setters and checkers to allow more credit to be given to previously seen material; the switch (from 2009) to a choice of two questions out of three on each half-unit instead of two questions out of four; (from 2011) a separate 1.5 hour examination for each half-unit. The latter changes have brought benefits, but may have had the unintended consequence of encouraging candidates to focus on learning bookwork across a wide range rather than being selective, and so to have devoted less time and effort on developing other skills. Also candidates no longer have scope to divide their time unequally over paired half units examined together or to puzzle over a non-standard problem sporadically over a 3-hour period.

On teaching and learning, we note that the resources available to students in support of the courses have greatly increased over recent years. This year virtually all Part B Mathematics courses examined by traditional written papers have notes provided on the web: in very many cases these are full lecture notes; in a few they are notes written by a previous lecturer for the same or a similar course. In a few cases solutions to problem sheets are also posted on the web. We note also a recent request from the student body for archival lecture material to be made available. A discussion paper on the pros and cons of notes on the web was presented by Dr Earl at the meeting of JCCU in Hilary Term 2013. This is admirably well balanced, but we observe that it does not consider at all any implications the provision of full notes may have for assessment. At the least, the availability of such notes must be encouraging students to use these as a basis for their examination preparation, so leading to stereotyped answers to material directly covered in the course.

Class problem sheets should provide the platform whereby students develop their individual problem-solving skills. But we note that problem sheets for many courses change little if at all from one year to another. The expenditure of time and effort involved in producing or updating web notes may act as a disincentive to lecturers to changing course notes and so too to refreshing the associated problem sheets. Even where solutions are not put on the web after classes there is evidence that solutions do get into the public domain. (Of course students are ill advised not to work problem sheets independently, but many won't if they can avoid it.)

There has been pressure over a long period from students and through Divisional channels for 'model answers' to past examination questions, or at least explicit guidance on what is expected in examination answers. Teaching Committee has recently agreed that in future sample answers will be provided to one past paper (or the equivalent thereof, drawn from several papers). Additionally it has been suggested that assessors should be actively encouraged to make their reports helpful to students using past examination questions for revision. These developments must have the effect of bringing more of the material to be examined into the category of 'seen before'.

2. Paper C7.1b: Quantum Theory and Quantum Computers

This is a Part C option, at M-level, which may be offered also by Part B candidates. The setting and marking are the responsibility of the Part C examiners and assessors, and the USMs for the Part C candidates are determined using the scaling algorithm as it applies to Part C. The USMs for the Part B candidates are then derived using the Part C scaling map. These are passed to the Part B Examiners, along with an 'examiner fairness' plot. Should this plot appear to show a lack of alignment, the Part B examiners do not have sufficient information on which to base a decision to make adjustments.

This year, 5 Part C candidates took the paper and 22 Part B candidates (19 in Mathematics, 3 in Mathematics & Philosophy). These numbers call into question the validity of Part B USMs derived solely from the Part C scaling map, the more so because with very small numbers the algorithm cannot be expected to produce a reliable result even for Part C without adjustments being made by hand by the Part C examiners.

It is appropriate that, given the M-level status of the corse, the Part C examiners should continue to have primary responsibility for it. However we suggest that the procedure for arriving at USMs for Part B candidates needs to be improved.

We PROPOSE the following procedure for 2014:

(a) the raw marks for C7.1b for Part C candidates should be entered in the Part C database, and those for Part B candidates should be entered in the Part B database;

(b) the two programs should be run separately to determine a potential scaling map for each cohort;

(c) the Part C examiners (assuming they meet first) should consider both potential scaling functions, and then determine the scaling maps to be used (which may be neither of the two potential maps);

(d) the Part C examiners should pass an assessor's report to the Part B examiners.

A side-effect of (c) would be better compliance than at present with the principle that, on a given unit of assessment, work of equal quality should be equally rewarded irrespective of the examination for which it is submitted.

We suggest, more radically, that the provision for sharing courses between Parts B and C is inherently unsatisfactory and RECOMMEND, for the new Parts B and C:

(a) that no course should be available in both Parts B and C;

(b) where, in exceptional circumstance, (i) is impossible, there should be different units of assessment for the two cohorts, but with substantial overlap.

Clause (b) is common practice in other universities. The additional assessment for Part C could be any of

- a mini-project;
- answer one extra, deeper, question (possibly with extra time);
- insertion of something a bit deeper in each question.

3. BSP: Structured Projects

The 2012 examiners made recommendations to Teaching Committee for a review of aspects of the assessment of BSP. No action was taken. This year's examiners had similar concerns to those of their predecessors, specifically in relation to the high marks awarded by the assessors to candidates for the presentation (counting 20% to the total) and and peer review (counting 10%); these marks were in percentage terms frequently well above those for the written report. We do not question due credit being given for the demonstration of transferrable skills not explicitly taught within the course. But we do doubt whether the credit presently available is proportionate, given that candidates offering most other papers do not have the opportunity to have the same skills tested.

Very constructive discussions were held with the organisers of BSP following this year's assessments and we report in Section A (Determination of University Standardised Marks) on the way in which, with their full agreement, adjustments were made to this year's provisional USMs. The Chairman of Examiners, Dr Stedall and Dr Wilkins will be presenting to Examinations Committee a paper putting forward suggested amendments to the BSP guidelines and refinements to the assessment process. These will include a proposal to alter the 70%/20%/10% split to give somewhat greater weight to the written report, the use of longer marking scales (to allow better discrimination), and for the presentation to be assessed with reference to a checklist of specified criteria.

4. Responsibilities of assessors and related issues

Oxford's Public Examination system has a crucial role in maintaining the highest academic standards, and those appointed as assessors in University examinations do have a very important part to play in this. We acknowledge, of course, the competing demands on academics' time and the considerable burdens that examining imposes within a hectic schedule, and also the steep learning curve confronting new appointees.

Leaving aside papers moderated by non-traditional means, there are 27 Part B papers for which traditional examinations have to be set, checked and marked (to increase to 28 from 2014). As recorded in Section A of this report, failure by many assessors to meet deadlines was a major issue this year, and this enormously increased the burden on the examiners and on the staff in the Academic Office. This is not a new problem—the Examinations Committee discussed it on two occasions in 2012/3—but it has become progressively more acute.

It was clear this year that not every Faculty member nominated to take on a Part B course was fully aware of what was entailed: question setting and checking; responding at short notice to queries and comments from internal and external examiners; signing-off CRC at the due time; availability, when possible, for attendance at Examination Schools; marking scripts and being contactable in case of queries on these scripts. These tasks are an essential and integral part of the examining process (as set out in the Examination Conventions) and must be performed in a timely manner by all assessors if the procedures are to work smoothly. We are pleased to be able to commend a number of relative newcomers on the way they have got to grips with the minutiae of a necessarily complicated system, met deadlines, and carried out their duties admirably.

By no means all assessors read with due care the carefully presented information on setting and checking supplied to them. For example: some checked papers were submitted without the required mark scheme and/or without the designation of which parts of questions were B(bookwork), S(imilar to seen material), or N(ew). This is crucial information for the examiners. We were grateful to those assessors whose mark schemes and B/S/N classification were very clearly presented on their model solutions, whether typeset or handwritten. In other cases setters had to be called in to decode what they had supplied. An example of good practice might usefully be provided to future setters. We note also that a number of errors which a spellchecker would have caught survived in the versions submitted (in undue haste?) to the examiners. In a few cases errors in English usage were too serious to be overlooked. We suggest that checkers should be urged to be alert to such problems.

The instructions to setters request that submitted papers are typeset with the oxmathexam LaTeX class file and associated file standardmacros.sty, and a template file with examples and do-s and don't-s is supplied. It is made clear that anyone experiencing difficulties with typesetting may contact the Academic Office for assistance. Notwithstanding, failure to use the class file properly, or at all, is widespread and a lot of work is needed by examiners and Academic Office staff to edit submitted files to generate papers of CRC quality. On administrative grounds and to reduce potential errors, assessors should be strongly encouraged to produce their draft papers using oxmathexam.cls and the formatting commands therein. We recommend that the Department's class file should also be adopted as the default for Collections. This would assist in making it, and its advantages, better known to Faculty members. [This paragraph was written by, and is strongly backed by, this year's Chairman. Next year's Chairman dissents, and favours more responsibility for typesetting being borne by the Department, with a suitably qualified person being assigned to assist the examiners in preparing and editing papers.]

There are a number of ways, most already discussed or in train, in which information to Part B (and Part C) lecturers could usefully be improved:

(a) formally, through the Teaching Committee's Standing Orders, and, less formally, through the circular to Faculty members on allocation of lecture courses and through enhancement of consolidated guidance on the Department's website;

(b) a summary for assessors of their obligations in this role, to accompany the present letter to setters and checkers concerning question setting, along with a cut-down version of the timetable for the examining process that is circulated to the examiners, to include the dates relevant to their individual involvement;

(c) induction in Michaelmas Term for Faculty members on Oxford examining, aimed at those with little or no experience of the process and the obligations it involves;

(d) mentoring of inexperienced assessors by experienced colleagues to confirm that marking is consistent and carried out to the highest standards. (A seminar on marking is already held annually in Trinity Term, and should continue.)

We believe that all these initiatives would be extremely helpful. Indeed we regard item (a) as necessary, but we are not aware that work in this direction has yet gone far enough. We note that this will not assist for the 2014 examinations, since lecturers for Part B courses have already been appointed.

We also ENDORSE the suggestion made by one of this year's external examiners that each assessor should be supplied with the data applicable to his/her paper, including the default scaling map, in advance of providing comments for the examiners. This data is generated for each paper individually, and so can be produced once the checked marks have been entered into the database. This procedure would enable assessors to comment more authoritatively on positions of borderlines in relation to the raw marks awarded, and would give them immediate feedback on how well their paper had worked. Assessors' comments would, as now, need to be supplied in time for these to be taken into account at the non-plenary examiners' meeting at which changes to the default scaling maps are first discussed.

E. Assessors' comments on sections and on individual questions

The comments which follow were submitted by the assessors, and have been reproduced with only minimal editing. The examiners have not included assessors' statements suggesting where possible borderlines might lie; they did take note of this guidance when determining the USM maps. Some data to be found in Section C above have also been removed.

B1a: Logic

Question 1 This question was generally very well done with just minor slips and omissions. Everyone attempted this question.

Question 2 Most candidates attempted this question. Part (a) was well done, though (iii) generated some confused arguments. In (b), there was some carelessness with stating and applying the deduction rules. The derivation in (iv) caused difficulties to many. For (c), part c(i) was done with mixed success, students struggled to write down sentences with the required properties, while very few made any headway in (c)(ii).

Question 3 Fewer students attempted this problem. There were not too many difficulties except in part (c)(iii), which students found very difficult. It was typically recognised that a set of formulae forcing the domain to be infinite would be required, but not how to deploy this and compactness to get the required implication.

B1b: Set Theory

Question 1 As virtually nobody got credit on (b)(ii) and lost bits and pieces on (c)(ii) and (d)(ii) (and sometimes (b)(ii)), this was perhaps the hardest of the 3 questions to score well on.

Question 3 Was perhaps the easiest question to do well on, with a lot of very standard bookwork worth a lot of points.

B2a: Introduction to Representation Theory

There were very few students who showed little understanding of the material of this course. Overall, students displayed a good knowledge of bookwork, but they had problems with applications of the subjects. All three questions showed approximately equal popularity, with Question 1 being the most popular.

Question 1 Part (a) generally was well answered. Despite part (b) involving standard concepts from the course, there were a substantial amount of problems with writing down a composition series of the algebra, and then with the classification of simple modules. Part (b)(iii) was rarely answered and indeed contains one of the most difficult parts of the course.

Question 2 Surprisingly there were problems with the example in part (a)(i). Bookwork was generally well done. Students had good understanding of part (b), although some constructed a two dimensional non-simple module, namely a direct sum of two one dimensional modules. Surprisingly many students found part (c) difficult, which, in a simple way, tested for understanding and easy application of some fundamental theorems of the course.

Question 3 Bookwork part (a)(i) was generally well done; quite a few students had a gap for bookwork (a)(ii). Bookwork part (b) was well done. While there were different ways of answering part (c) of the question, and there have been a few students finding these different answers, many students had problems with answering this part of the question. About half of the students made the correct guess for the answer without being able to justify it. Generally people understood only parts of the arguments in part (c), for example how to apply the Chinese Remainder Theorem.

B2b: Group Theory and an Introduction to Character Theory

Question 1 (Sylow's theorems and solubility) There were many good solutions. Generally candidates understood the topic.

Question 2 (Jordan-Hölder Theorem) Good solutions, though in the second part, many missed that the Klein 4-group has three composition series.

Question 3 (Character table) As well, good solutions. Part (iv) was the hardest part.

B3a: Geometry of Surfaces

Question 1 As in previous years, the question on classification of topological surfaces was popular and done well by the majority of candidates, with three quarters obtaining at least 20 marks. Marks were lost even by good candidates for a lack of precision in parts (a)(i) and (b).

Question 2 Two thirds of candidates attempted Question 2. All were able to state the Riemann–Hurwitz formula reasonably well, but many lost marks by giving inadequate definitions of the terms involved.

Most candidates realised that part (c) was an exercise in the use of the Riemann–Hurwitz formula but only the very best candidates gave a reasonable explanation of why the degree of f and the indices of the ramification points were divisible by 3 (or, alternatively, were at least 3), and why the fixed points of τ were ramification points. Several candidates tried to prove that the index of f was exactly 3 (which it need not be).

Question 3 Five out of twelve candidates attempted this question with two giving near perfect answers. The weaker candidates lost marks with inaccurate bookwork as well as on the more challenging part (c).

B3b Algebraic Curves

Question 1 was found reasonably straightforward, with quite a lot of people enjoying the curve plotting part.

Question 2 seems mostly to have been of the right difficulty. Part (d) was easier than intended, since a quadruple line was also an example, which several people discovered (sometimes implicitly); I should have asked for an irreducible quartic. There were some difficulties with the very end of the question.

Question 3 while not harder, was on material from the end of the course, which people presumably felt a lot less comfortable with.

B3.1a Topology and Groups

Question 1 was on homotopy equivalence and the fundamental group (definition and calculations). Part (a) was done well. Part (b) was bookwork. Some students had trouble showing that the fundamental group is independent from the basepoint. They generally defined the homomorphism that changes basepoint but failed to note that there is an inverse homomorphism (which shows that it is an isomorphism). Parts (i) and (ii) of (c) were done well. Part (iii) was more challenging, some students saw that the Seifert van-Kampen theorem should be used but failed to calculate explicitly the fundamental group of the resulting space. Quite a few students managed to do all parts of Question 1 with only minor omissions.

Question 2 was on free groups and presentations. Part (a) was generally well done but many students omitted to show that the group operation is well defined and points were taken off for this. In part (b) often the 'if' part was inadequately explained. In part (c)(i), (ii), (iii), (iv) were well treated by most candidates. Part (v) was more challenging and fewer students managed to do this. In part (vi) many students constructed K but some failed to observe that r induces a homomorphism—and some even claimed that r induces an isomorphism which is clearly false.

Question 3 was on covering spaces. Part (a) was bookwork and was generally well done. Part (b) was generally well done even though often some details were missing. Part (c)(i) was well done. In part (ii) many candidates said that a reflection of the picture is a covering transformation which is clearly wrong. Often the argument that the second covering space is not regular was imprecise. Part (iii) was bookwork but some candidates had difficulties with it. This is probably because this was a very substantial proof requiring a good understanding of the course. Part (iv) was the more challenging part but quite a few candidates did this.

I think all question contained substantial pieces of bookwork and I see no excuse for the candidates who did poorly.

B4a: Banach Spaces

Question 1 This question was the most popular but had the lowest average score. Most of the students completed the first part of the question without losing too many marks, only a few students forgot to justify that rational polynomials are dense in the space of all polynomials. Many proposed examples in part (b)(iii) were completely wrong: some of the proposed functionals were non-linear and some were ill-defined. Few students managed to solve (b)(iv).

Question 2 There were very few lost marks in part (a), but some used Hahn–Banach theorem in the last part without checking that the functional is bounded. The most popular mistake in the proof of isometry was the use of linearity for infinite linear combinations. In the last part of (b) many students misinterpreted the question and instead of one example with three properties tried to provide three examples with one property in each.

Question 3 This was the least popular question with the highest average score. In part (a) many students forgot to mention that the inverse operator should be bounded and that the spectrum is non-empty. In the tail of part (b) many students could not solve quadratic equations correctly.

B4b: Hilbert Spaces

The three questions turned out to be of similar difficulty, though Question 1 was much less popular than the other two. Few candidates seem to be competent in applying results from second year Integration. It was encouraging that so many candidates made significant progress with the tricky final part of Question 3.

B5a: Techniques of Applied Mathematics

As in previous years, most students did Questions 1 and 2 and only very few tried Question 3.

Question 1 The most challenging part of Question 1 was the additional hurdle to separate off Heaviside functions to get a continuous function g. Some students saw this and made good progress, but only very few got it completely right. In (a), there were some algebraic errors in computing the Green's function. Also, a number of students failed to supply the REAL general solution despite the bold font in the question, and this made the computation of the Green's function more difficult.

Question 2 Many students did well with Question 2, possibly because it is similar to previous exam questions. The challenge was to infer the eigenvalues for the given kernel by correctly making the connection to the Sturm–Liouville problem in (a) (or by explicit calculation of the Green's function, which was more tedious). Only very few students made previous years' mistake of (incorrectly) assuming the kernel was degenerate, however, some students appealed to FAT and the solvability condition but then reverted to incorrect arguments to answer the specific examples given in (c).

Question 3 Few students attempted this question.

B5b: Applied PDEs

Question 1 Most candidates made good progress with parts (a) and (b). Few were able to tackle or complete the more demanding part (c).

Question 2 Most candidates were able to reproduce the maximum principle for this unseen problem in part (a). Many students failed to use stated similarity solution in part (b) and tried instead to derive the stated form before continuing with the question. Few candidates were able to determine the explicit solutions for f and g in part (c).

Question 3 Most candidates scored well on this question, managing to reproduce the bookwork in part (a) and to apply it in part (b). Part (c) was more challenging, with few candidates able to identify the domain of definition.

B5.1a: Dynamics and Energy Minimization

Question 1 One moderate and one good answer.

Question 2 One good and one near perfect answer.

Question 3 No Attempts.

B6a: Viscous Flow

Question 1 This question was well answered by almost all candidates. Some candidates lost marks in the first parts by not defining any/all of the terms that they introduced in their definitions in Reynolds' transport theorem, the definition of the stress tensor and Cauchy's stress theorem.

Derivation of the equation for conservation of momentum was completed well by all candidates, demonstrating a clear understanding of the concepts required here.

The calculation of the flow field in part (b)(i) and the flux in (b)(ii) were well completed. Some weaker students were aided by the statement in the question of the required velocity that needed to be shown.

(b)(iii) served as a good separator of the candidates. This was completed successfully by more than half of the candidates. Some candidates were unable to calculate the stress, while others confused the limits of integration when calculating a total drag (using the separation between the plates). Many made algebraic errors in forgetting to carry through the viscosity that premultiplies the velocity gradient when calculating the shear.

Question 2 Part (a) of this question transpired to be a good separator of candidates. Almost all students were able to define the Reynolds number, but many did not correctly define the terms introduced in this expression.

Part (b) was successfully completed by almost all candidates.

In part (c) many students did not complete the final steps leading to the boundary condition $\psi(x, 0) = 0$, from $\partial\psi/\partial x(x, 0) = 0$. Determining the two possible solutions for c in part (e) proved difficult for some candidates and served as a good separator of candidate classes. Some candidates had difficulty finding the velocity but many of these students were subsequently able to show the final result concerning the shear by using the result given.

Question 3 This question was attempted by the fewest candidates, but those who attempted this achieved high scores.

Candidates completed the bookwork in part (a) of this question well, demonstrating a sound understanding of the material.

Some students were unsure why the boundary conditions $p(\pm 1, t) = 0$ in part (c) could be replaced with the symmetry conditions.

Candidates completed the latter parts of this question well, aided by the results given in the paper to be proven.

B6b: Waves and Compressible Flow

Question 1 This question was well done in general and proved popular. It was particularly pleasing to see that the majority of candidates understood that the radiation condition was required for part (b). One common failing in part (a) was not to write down expressions for the pressure and density perturbations in terms of the velocity potential ϕ (which have generally been derived as part of the derivation of the wave equation for ϕ) but instead to simply write down the wave equation for these quantities. This had later implications for the successful completion of (c)(ii).

Question 2 A large number of candidates were not able to complete the bookwork that led to the equation (‡), despite having been able to do much the same calculation in Question 1. Most candidates opted for a rigid (no flux) boundary condition in (b)(i) rather than translating the given boundary condition on p' into the intended boundary condition on $\partial\phi/\partial x$. Those that did use the correct boundary condition generally managed to complete the remainder of part (b).

Question 3 This question was generally well done. In part (b) the explanations of why the C_- characteristics must be linear in the expansion fan were not always clearly and logically presented. In part (c) candidates generally did not demonstrate *why* the two sets of C_- characteristics have to intersect (e.g. by calculating the slopes of the two sets) but instead stated this as a fact supported by a sketch.

B7.1a: Quantum Mechanics and Electromagnetism

Question 1 Most students got parts (a) and (b) correctly. On the other hand, most students got the first half of part (c) correctly, while very few got the second half of part (c) (regarding the need for a consistency condition on the source terms) correctly.

Question 2 The average mark was slightly lower than expected. A very large portion of students failed to understand what was being asked at the beginning of part (b), compromising the rest of this part. On the other hand, part (c) was independent of this.

Question 3 While the average mark appears to be quite low, several low marks were due, apparently, to the fact that many students attempted this question with not much time left.

C7.1b: Quantum Theory and Quantum Computers

Information on this course may be found in the Part C Examiners' Report.

B7.2b: Special Relativity and Electromagnetism

Question 1 : A straightforward question on Lorentz transformations, with no tricky rider, this was well done.

Question 2 The 4-momentum question, comparable with recent years and well done.

Question 3 About as straightforward an electromagnetism question as could be imagined, this was still avoided and the average mark was lower than the other two.

B8a: Mathematical Ecology and Biology

Question 1 Virtually everyone attempted this question and the answers were of good quality.

(a) a number of people confused "linear stability" with "linearly stable".
(b)(iii) Bizarrely, some candidates resorted to cobwebbing for stability.
(c)(ii) No one could argue this correctly.
(c)(iv) almost everyone got this wrong because they misinterpreted the definition of hysteresis as given in the printed notes so I was generous (only one mark for this part).

Question 2 Most candidates made good attempts at (a)–(d). Part (e) of this question was very challenging and proved beyond most candidates.

Question 3 (a)(i) Virtually no one got this definition correct.
(a)(ii) A number of candidates simply stated that eigenvalues of the Jacobian needed to be negative, without giving any reasoning. There was a subtlety right at the end that no one got correct.
(a)(iii) Most candidates did not realise that modes needed to also satisfy the boundary conditions.
(b)(iii) Although self-evident from this part that we are now on a variable-sized domain, some candidates still thought the domain was size 1, which makes the question nonsensical.
(b)(iv) Surprisingly, most candidates did not answer this correctly.

B8b: Nonlinear Systems

Question 1 Nearly everyone who attempted this question did a good job. The problems came in the accurate derivation of the amplitude evolution equation. No-one solved this equation to get the general form for the amplitude. Most guessed this from their form of the evolution equation.

Question 2 This was the easiest question on the paper. There were many nearly perfect solutions.

Question 3 Least popular, but with some very nice solutions. The definitions of periodic and nearly periodic were incomplete, and their applications to one of the definitions of Chaos were also incomplete.

B9a: Galois Theory

In Questions 1 and 2 students showed a good command of the bookwork and used this knowledge well to tackle the unseen parts of the questions.

Question 1 Points were lost in the part which asked about the reducibility of the equation of degree 4 in part (b)(i), in fact not many got the right answer. Also, students found hard part (b)(ii).

Question 2 There were many sloppy discussions on the Galois group in part (b) and not many got the equation for $p = 7$ in part (c).

Question 3 There were only a few attempts. This question was different from most of the questions in past exam papers, however this setter thinks this was a rather interesting question.

B9b: Algebraic Number Theory

Question 1 was answered by the fewest candidates, but was generally well handled by most of those who did attempt it. Part (a) was bookwork and was answered well. Most candidates answered some, but not all, of the components of part (b).

Question 2 was answered by a large number of candidates. Parts (a), (b)(i)–(iv) were generally well answered; only a few candidates were able to work through all steps of (b)(v).

Question 3 Part (a) was bookwork and part (b) was a class group computation, both of which were generally well answered. Parts (c) and (d) proved difficult, particularly part (d).

B10a: Martingales Through Measure Theory

Question 1 was the most popular. The bookwork was generally completed well. The extension (to three σ-algebras) caused some trouble. The final part of the question is not as straightforward as it seems, and was not completed correctly by any candidates, though there were some decent attempts. One method is to note that $I = \{\{X < x, Y < y\} : x, y \in \mathbb{R}\}$ is a pi-system which is independent of $J = \{\{Z < z\} : z \in \mathbb{R}\}$, and that $X + Y$ and Z are measurable with respect to $\sigma(I)$ and $\sigma(J)$.

Question 2 was almost as popular as Question 1. The bookwork was again completed well, though a significant number of candidates wrote more than was necessary, writing out the proof of a more general version of (b) as in lectures without noticing that it simplifies considerably with the assumption given here. The last part contains a small subtlety correctly addressed by only a few candidates: to meet the bounded differences condition in (b) one must first replace M_n by $M_{n\wedge\tau}$.

Question 3 was attempted by rather few candidates.

B10b: Mathematical Models of Financial Derivatives

Question 1 This was the least popular question, with some excellent attempts. Most of the material was standard, though some candidates did not use the most efficient way of computing the variance of the sample quadratic variation minus time. Some forgot to include continuity of Brownian motion as one of its properties in defining it. This was a technical question, although mainly standard material, so it seems that strong candidates tried it, and there were relatively few (but by no means no) very poor attempts.

Question 2 The question was standard material, seen in lectures. There were very many reasonable but slightly erroneous answers, with a few excellent ones. The most common error in part (a) was in part (i), and was to condition on non-random rather than random starting values of the processes when proving the martingale property of M. In part (b) a large number of candidates thought the Asian price was either a function of $(t; S_t)$ or of $(t; I_t)$, rather than of time and both the stock price and the average (that is, of $(t; S_t; I_t)$), even though this topic was covered in one of the lectures. The result was a question that although straightforward, produced relatively average performances.

Question 3 The most popular question, done by nearly all candidates, as it was a discrete-time binomial tree question. For the most part it was done reasonably, but not always perfectly. Apart from the last part (e), it was all standard material, so one would have thought it would produce slightly better answers. Common mistakes were to over-complicate the replication argument, and to fail to show both implications of the equivalence between no-arbitrage and the condition $u > 1 + r > d$ on the parameters. Nearly everyone struggled with part (e) which was non-standard, though there were some decent attempts. The most common error was to not realise that the transaction cost is charged at time zero, when the initial portfolio is created.

B11a: Communication Theory

The paper seems to have been successful; almost everybody found something they could do, and some candidates did very well indeed.

Question 1 The most popular question, much of which was well done. Given that part (c) had been previously seen by the candidates as a question on a problem sheet, there were considerably fewer successful attempts at this part than had been anticipated.

Question 2 The first part of this question covered standard material, and was generally well done. Part (b) was a non-standard application of conditional entropy; and, while several solutions scored an alpha, a disappointing number failed to apply their own [correct] definition of conditional entropy accurately.

Question 3 This covered a part of the syllabus that is examined relatively infrequently, and that is no doubt the reason why this was the least popular question. Nevertheless, there was a pleasing number of very good attempts, several of which were excellent.

B11b: Graph Theory

Question 1 was the most popular, attempted by almost all candidates. It turned out to be rather too long in practice, even though it is possible to give a very short answer to most of (b) by first observing that any graph G can be obtained from a spanning forest by adding $n(G)$ edges, each of which creates at least one new cycle. The bookwork was mostly well done, as was (b)(i), but most candidates struggled with the rest, or gave very long answers by considering unnecessary cases or unnecessary additional induction arguments.

Surprisingly many candidates omitted to show that any connected graph contains a spanning tree; in many cases this seemed to be just an oversight.

Question 2 was reasonably well done, although often the logic of part (a) was not very clear. In part (b) rather few candidates made the key point that since the intersection is complete, all its colourings are equivalent to one another, so each extends to the same number of colourings of G_2. (The arguments given would in most cases have applied equally to the case of non-complete intersection, where the analogous statement is false.)

Question 3 The first part asks for one of the two main variants of the Max-Flow Min-Cut theorem. Some candidates confused the two variants, stating a mixed form that did not make sense. Many candidates omitted some necessary details or stated them incorrectly. The later parts of the question were generally well done.

B21a: Numerical Solution of Differential Equations I

Question 1 Linear multistep method, analysis of particular second order explicit method and absolute stability. Answered by all candidates, generally well done, definitions and basic theory well understood, quite a few failed to consider an explicit method (and so carrying an extra parameter), many did not realize that there was a one parameter family of schemes, absolute stability definition understood by only a few correctly completing that section.

Question 2 Derivation of error bound and proof of convergence for a one step method, examination of a theta method and explanation of step length adaptivity. Around a half of solutions equated consistency with convergence whereas other half correctly proved convergence for this scheme. Many did not deal with the general theta method when determining truncation error but went straight to the specific case at the end of that part. Only a few understood adaptivity. Not well done considering that the entire question came from lectured material.

Question 3 Examination of a number of given schemes for solutions of a diffusion equation. Only a handful of solutions, most middling. Only a few considered both error and stability in examining the schemes.

B21b: Numerical Solution of Differential Equations II

Question 1 This question was attempted by most students, with overall high scores reflecting a good understanding of linear boundary value problems.

Question 2 This question was attempted by most students, with high scores, though with less variability showing that most students knowing how to completely solve a portion of the questions or be unable to solve the portion. Part (c) typically received scores of zero or five out of five, with intermediate solutions uncommon.

Question 3 This question focused on iterative algorithms to solve the linear systems of equations resulting from the discretisation of the differential equation. A small fraction of students attempted this question, but those that did were typically able to secure points through partial answers to sections of the questions.

B22a: Integer Programming

Questions 1 and 3 saw a larger uptake than Question 2. The three questions covered the material of the course quite widely. There was a fair amount of bookwork on each question, coupled with some more challenging problems that gave the stronger students an opportunity to distinguish themselves.

BSP: Structured Projects

Assessment for this course is in three parts: a project completed at the end of HT (70%), a peer review completed over the Easter vacation (10%) and a presentation given at the start of TT (20%).

This year students were offered a choice of three topics: mathematical finance (chosen by 5), thermohaline circulation (12), and modelling of the cerebro-spinal infusion test (4).

Written projects and peer reviews were double-marked by two assessors, a different pair for each topic. Oral assessments were also double-marked, by a different pair of assessors. The standard of the oral presentations was high and often excellent. Marks overall on the three parts together were generally in line with candidates' marks on other papers.

O1: History of Mathematics

The examination is in two parts: an extended essay submitted on the first Friday of the Easter Vacation 2013 on the topic of the Hilary Term reading course, *Lagrange, Bolzano, Cauchy, and the beginnings of rigorous analysis* and a 2-hour examination paper in June 2013, in which the candidates are asked to comment on the context, content and significance of two (from a menu of six) passages of mathematical writing chosen from the period 1600-1900 and also to write a more general essay on a set topic (chosen from a menu of three). Both parts of the examination were blind double-marked. The raw marks were not, as it happens, very far apart, and reconciliation to a final mark was not difficult.

O1 extended essays, Easter vacation 2013

The marks on the extended essay were contained in a smaller range than we had expected on the basis of weekly work during HT. Generally, the candidates addressed the question as it had been set; some showed quite sophisticated feeling for the mathematics of the late 18th and early 19th centuries. All the candidates treated the main primary sources in some detail; all of them used a wide range of apposite secondary sources, though some used them with more critical insight than others did. Presentation – grammar, style, referencing – ranged from fair to good, though all the essays contained infelicities of one kind or another.

O1 paper, June 2013:

A1 DESCARTES *Géométrie,* 1637: this question attracted only one answer.

A2 NEWTON on the parallelogram of forces, 1687: this question attracted no answers.

A3 EULER on functions, 1748: in general the four answers dealt reasonably well with context and significance, showing a good understanding of the development of the notion of function in the 18th century, but showed little engagement with the actual content of the piece.

A4 BERKELEY on increments, 1734: the question was generally well done.

A5 CAYLEY on matrices, 1858; this question attracted no answers.

A6 DEDEKIND on irrational numbers as sections of $\mathbb{Q}$, 1872: of the three answers to this question, one was excellent, the others were fair. Those two confused context and significance, but contained good sense on the content of the extract.

B1 Newton's contributions: no candidate tackled this essay.

B2 Dissemination of ideas: the three answers showed some gratifyingly original thinking from all parts of the course.

B3 Changing perceptions of rigour: two of the three answers were of first-class standard; the third was a little limited, but adequate. Most of the focus was on rigour in calculus or analysis, but examples from other areas, such as geometry and algebra, were also deployed.

Following the rubric, the two parts of the examination were given equal weight. It was noticeable that the candidates' marks were roughly consistent across those two parts.

N1a: Mathematics Education

Assessment of this course was by one written assignment (35%) and a presentation in MT (30%), and a further assignment handed in at the start of HT (35%). One written assignment involved annotated mathematical exploration, the other a brief essay. All parts were double-marked by the same pair of assessors, and apart from the presentations the marking was blind.

All work was completed on time and to a high standard. We were impressed by the analytical and critical qualities of most writing, showing application of new ideas to familiar territory and a willingness to develop new ways to think about education informed by research and other literature. Much of the work was outstanding. There were no serious weaknesses other than the one weak student withdrew from examination of the course, which was a good decision.

N1b: Undergraduate Ambassadors Scheme

The assessment of the course is based on:

- A Journal of Activities (20%)
- An End of Course Report, Calculus Questionnaire and write-up (35%)
- A Presentation (and associated analysis) (30%)
- A Teacher's Report (15%)

The Journal and Report were double-marked with Nick Andrews and myself (Dr Earl) as assessors. Nick was the sole assessor for the Presentation. Each part was awarded a USM, and then an overall USM was allocated according to the weightings above.

Statistics Options

Reports of the following courses may be found in the Mathematics & Statistics Examiners' Report.

OBS1a: Applied Statistics I

OBS1b: Applied Statistics II

OBS2a: Foundations of Statistical Inference

OBS3a Applied Probability

OBS3b Statistical Lifetime Models

OBS4a: Actuarial Science I

OBS4b: Actuarial Science II

Computer Science Options

Reports on the following courses may be found in the Mathematics & Computer Science Examiners' Reports.

OCS1: Functional Programming and Design and Analysis of Algorithms

OCS3a: Lambda Calculus & Types

OCS4b: Computational Complexity

Philosophy Options

The report on the following courses may be found in the Philosophy Examiners' Report.

102: Knowledge and Reality

122: Philosophy of Mathematics

F. Comments on performance of identifiable individuals

Removed from public version.

G. Names of members of the Board of Examiners

- **Examiners:**
  Prof. C Batty
  Prof. P Candelas
  Prof. J Lister (External)
  Dr A Muench
  Prof. H Priestley (Chairman)
  Prof. G Seregin
  Prof. R Thomas (External)
  Dr M Winkel

- **Assessors:**
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  Dr N Andrews
  Prof. Sir John Ball
  Dr D Belyaev
  Prof. M Bridson
  Prof. H Byrne
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  Dr R Earl
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  Dr B Szendroi
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  Dr J Dyson
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  Dr I Hewitt
  Dr H Jin
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