Examiners' Report: Final Honour School of Mathematics Part B Trinity Term 2012

August 30, 2012

Part I

A. STATISTICS

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

  See Table 1.

	Numbers					Percentages %				
	2012	(2011)	(2010)	(2009)	(2008)	2012	(2011)	(2010)	(2009)	(2008)
I	57	(54)	(55)	(61)	(53)	34.34	(36.24)	(35.71)	(36.09)	(34.19)
II.1	79	(67)	(61)	(76)	(74)	47.59	(44.97)	(39.61)	(44.97)	(47.74)
II.2	21	(19)	(28)	(23)	(22)	12.65	(12.75)	(18.18)	(13.61)	(14.19)
III	5	(7)	(9)	(5)	(5)	3.01	(4.70)	(5.84)	(2.96)	(3.23)
P	3	(2)	(0)	(3)	(1)	1.81	(1.34)	(0)	(1.78)	(0.65)
F	0	(0)	(1)	(1)	(0)	0	(0)	(0.65)	(0.59)	(0)
Honours (unclassified)	1	(0)	(0)	(0)	(0)	0.6	(0)	(0)	(0)	(0)
Total	166	(149)	(154)	(169)	(155)	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

The format of the examination papers was changed, with whole-unit papers no longer being produced for any subjects examined wholly through traditional written examinations. This allowed a USM to be reported for each half unit offered by a candidate.

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 6 February 2012 and the second notice on 30 April 2012. These notices can be found at https://www.maths.ox.ac.uk/notices/undergrad/part-b, and contain details of the examinations and assessments.

The Examination Conventions for 2012 examinations are on-line at http://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 Helen Lowe for her exemplary efficiency in providing really excellent administrative support, Charlotte Turner-Smith for her help and support whenever this was needed, and Margaret Sloper for her assistance during the process of logging in and checking scripts. 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. He was admirably assisted this year in running the database during examiners' meetings by Helen Lowe. We are also grateful to Keith Gillow for facilitating the introduction of a new LaTeX class file tailored to Oxford examination papers. This worked well and saved the examiners time, in that it is made it more difficult than hitherto for setters to submit idiosyncratically formatted papers.

The internal examiners would like to express their gratitude to Professor Gordon and Professor Lister 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' meetings.

Timetable

Examinations began on Monday 28 May and finished on Thursday 16 June. Because of the move to half-unit examinations the examination period was longer than in previous years, with an earlier start. This caused no difficulties.

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 2011. 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 Section 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.

The questions were initially set by the course lecturer, in almost all cases with the lecturer of the corresponding half unit (and the Subject Panel Convenor) involved as checkers before the first drafts of the questions were presented to the examiners. This year almost all papers were submitted by the notified deadlines. In the isolated cases in which deadlines were not met, additional burdens were placed on the examiners and the Academic Office.

The internal examiners met at the beginning of Hilary Term to consider the draft papers on Michaelmas Term courses. 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 next meeting considered the external examiners' comments and the assessor responses, making further changes as necessary before finalising the questions. Camera ready copy of each paper was then signed off by the assessor. The process was repeated for the Hilary Term courses, but necessarily with a much tighter schedule since CRC for all papers has to be submitted to the Examination Schools in week 1 of Trinity Term.

The checking process proved to be entirely robust except in the case of one paper in which typographical errors were regrettably present in the final version despite all steps in the checking procedure having been duly carried out in the normal way. Comments are made below on the steps taken by the examiners to ensure that candidates taking this paper were not disadvantaged, and in Section D on recommendations to be made to the Teaching Committee on how procedures might be enhanced to reduce the chance of a recurrence of a rare incident of this type.

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 by the due dates. A team of graduate checkers under the supervision of Helen Lowe sorted all the scripts for each paper of this examination, 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 those markers (the majority) who had adhered strictly to the marking instructions and whose internal additions were invariably, or almost invariably, correct. At the other extreme, some marking threw up numerous queries, some of them hard to resolve without reference back to the marker. Thus it is particularly important that any marker who will be absent from Oxford when script-checking takes place should be especially careful that their marking is totally clear.

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 2011 Part B examination, and in particular recommendations made by last year's examiners, and the Examiners' Report on the 2011 Part A examination, in which the 2012 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 and the MPLS Divisional averages (with separate classification of Part C from 2008, there was this year five years' worth of past Part B data with which direct comparisons could be made);

- reports solicited from the assessors on the standard of the work presented for the questions they had marked, and including assessors' estimates of where they considered class borderlines might fall for the sets of scripts they had marked.

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 in previous years except that USMs were separately assigned this 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. Usually $U = 20$ but $U = 10$ was used for all of the Part B papers, see p. 7 for further discussion of this. 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. 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 final 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. In 2011, a substantial number of adjustments were required at the bottom end to ensure that candidates with raw marks in single figures were not given disproportionately high USMs. The 2011 examiners requested that in the algorithm determine the value of C_3 by continuing P_2P_3 so that it intersects the U axis at (0, 10) rather than (0, 20) to prevent or reduce this problem. The Mathematics Examinations Committee did not accept this recommendation, preferring to leave it to the 2012 examiners to make adjustments as they saw fit. This year the algorithm was run from the outset using $(0, 10)$ and this worked very successfully, giving appropriate scaling at the bottom end of the range with minimal adjustment being needed. Close attention was paid to the scaling of marks at the top end of the range, with account taken of assessors' comments on possible borderlines. For certain papers, in particular those with a significant number of very high raw marks, adjustments were made to achieve graphs for which the top segment was not too steep. Except in a very few cases the adjustments did not involve altering any of the default values 72, 57, 37 for the U-coordinates of the corners. In two cases additional corners were added to give an appropriate scaling.

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; in almost all cases the provisional scalings were deemed to be satisfactory and where adjustments were made these were small. 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 external examiner with appropriate expertise agreed to look in particular at scripts for Paper B5b, on which errors had occurred, especially those of borderline candidates; and one of the internal examiners was also requested to review how credit had been awarded to candidates whose answers had been affected by these errors. The other external examiner concentrated attention on one paper attracting relatively low marks and on several in pure mathematics for which there were a high proportion of very high marks. The examiners reconvened, with all Mathematics & Statistics examiners present, to confirm the scaling maps.

At their final meeting on the following morning, the Mathematics examiners reviewed the positions of borderlines for their cohort. Overall they were satisfied that, without further adjustments to the scalings, the class list was, in their academic judgement, in line with the candidates' performance. Before finalising the class list the examiners looked individually at the performance of candidates offering B5b and whose USM average put them just below a borderline. After careful reconsideration of these candidates' B5b scripts and the profile of raw marks, the USM marks on this paper were adjusted upwards for two candidates. In all other cases the examiners were confident that adjustment was not justified or that any adjustment that might be made would be too small to affect the candidate's class. Some concerns were expressed about the comparability of externally determined USM marks with those derived from the algorithm. It was agreed to make some downward adjustments to the marks supplied for the (first-year) paper OCS1 by the Computer Science Moderators. It was also suggested that the assessment criteria for BSP (Structured Project) might warrant review for the future, but the examiners made no adjustments to the USMs proposed by the assessors. The Strong Paper Rule had almost no effect this year in determining borderlines.

Table 2 on page 9 gives the final positions of the corners of the piecewise linear maps used to determine USMs. In accordance with the agreement between the Mathematics Department Database Working Group 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	Additional Corners	N_1	N_2	N_3
B1a	(11, 47)	(20, 60)	(34, 72)		13	26	7
B1b	(13.27, 37)	(23.1, 57)	(42.6, 72)		16	25	8
B2a	(15.05, 37)	(26.2, 57)	(35.2, 72)		14	10	3
B2b	(7, 29)	(11, 45)	(14, 49)	(18, 60), (34.6, 72)	10	10	2
B3a	(19.19, 37)	(33.4, 57)	(46, 70)	(48, 80)	5	6	1
B3b	(10.97, 37)	(19.1, 57)	(37.5, 72)		8	8	2
B3.1a	(13.04, 37)	(22.7, 57)	(39.2, 72)		9	7	1
B4a	(12.47, 37)	(21.7, 57)	(38.2, 72)		17	24	4
B4b	(12.81, 37)	(22.3, 57)	(35.8, 72)		16	19	4
B5a	(15.68, 37)	(27.3, 57)	(40.8, 72)		26	45	23
B5b	(15, 37)	(30.3, 57)	(42, 70)		25	40	21
B5.1a	(14.88, 37)	(25.9, 57)	(36.4, 72)		4	4	0
B6a	(11, 37)	(17.1, 57)	(36.6, 72)		21	37	16
B6b	(14.36, 37)	(25, 57)	(40, 72)		19	35	15
B7.1a	(11, 37)	(18, 57)	(37.4, 72)		14	29	9
B7.2b	(11.89, 37)	(20.7, 57)	(34, 70)		8	14	7
B8a	(10.63, 37)	(18.5, 57)	(41, 72)		18	44	21
B8b	(10.91, 37)	(19, 57)	(34, 72)		9	16	11
B9a	(14.02, 37)	(24.4, 57)	(41, 72)		18	16	3
B9b	(14.42, 37)	(25.1, 57)	(42, 72)		14	12	2
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 or above	%
92	1	1	0.6
90	2	2	1.2
85	3	4	2.41
84	5	5	3.01
82	6	6	3.61
81	7	8	4.82
80	9	10	6.02
78	11	13	7.83
77	14	17	10.24
76	18	22	13.25
75	23	23	13.86
74	24	27	16.27
73	28	35	21.08
72	36	41	24.7
71	42	50	30.12
70	51	57	34.34
69	58	67	40.36
68	68	76	45.78
67	77	81	48.8
66	82	91	54.82
65	92	101	60.84
64	102	106	63.86
63	107	116	69.88
62	117	121	72.89
61	122	132	79.52
60	133	136	81.93
59	137	140	84.34
58	141	142	85.54
57	143	146	87.95
56	147	148	89.16
55	149	151	90.96
54	152	153	92.17
53	154	156	93.98
52	157	157	94.58
51	158	158	95.18
49	159	162	97.59
44	163	163	98.19
38	164	164	98.8
35	165	165	99.4
33	166	166	100

The distribution of USMs at the top end shows a different pattern from that in 2011, with a smaller proportion of candidates gaining high first class marks overall. This is in line with, and in part determined by, the performance of this year's cohort in Part A in 2011. Around the II.1/II.2 borderline, candidates were generally able to demonstrate their capabilities quite satisfactorily, but performance fell off rather sharply below an average USM of 55.

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

Table 4: Breakdown of results by gender

Class	Total		Male		Female	
	Number	%	Number	%	Number	%
I	57	34.34	42	35.29	15	31.91
II.1	79	47.59	59	49.58	20	42.55
II.2	21	12.65	14	11.76	7	14.89
III	5	3.01	3	2.52	2	4.26
P	3	1.81	1	0.84	2	4.26
F	0	0	0	0	0	0
Honours (unclassified)	1	0.6	0	0	1	2.13
Total	166	100	119	100	47	100

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

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

The number of candidates taking each paper is shown in Table 5, on page 12. Individual question statistics for Mathematics candidates are shown below. For information on papers which are the responsibility of the Computer Science Department (OCS1, OCS3 and OCS4) see, respectively, the reports on Honour Moderations in Mathematics & Computer Science and Part B in Mathematics & Computer Science; USMs for Mathematics candidates taking these papers were provided by the examiners concerned.

Question statistics are not reported for the following papers as they were taken by fewer than 6 mathematics candidates.

OBS2a: Foundations of Statistical Inference

OBS3b: Statistical Lifetime Models

Table 5: Numbers taking each paper

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
B1a	46	25.07	9.16	63.35	13.31
B1b	48	34.9	8.89	69.04	12.47
B2a	27	33.26	7.05	69.04	12.44
B2b	22	24.77	12.1	61.5	18
B3a	12	43.92	6.54	76.33	16.66
B3b	18	32.72	8.3	69.5	10.35
B3.1a	17	36.47	6.27	71.76	8.85
B4a	45	34.29	7.35	70.51	10.42
B4b	39	32.74	8.03	69.67	12.43
B5a	96	33.34	8.31	63.77	12.9
B5b	91	36.31	8.49	65.12	13.04
B5.1a	8	34.5	5.32	70.12	8.95
B6a	78	26.94	9.63	63.09	13.82
B6b	72	31.79	8.58	63.26	12.9
B7.1a	55	26	9.57	61.89	12.15
B7.2b	29	30.34	8.82	67.1	13.76
B8a	84	29.19	9.01	64.26	9.17
B8b	39	25.94	6.44	63.87	7.53
B9a	37	38.86	8.27	74.62	13.83
B9b	28	39.43	7.71	73.54	12.95
B10a	30	32.7	7.12	68.4	9.97
B10b	54	27.26	10.1	61.7	17.39
B11a	27	30.19	7.48	62.59	9.41
B21a	33	34.06	8.08	67.21	14.03
B21b	25	36.28	8.66	66.16	13.06
B22a	16	29.88	11.41	62.12	19.03
OBS2a[1].	1				
OBS3a/B12a	49	34.14	7.96	65.24	13.33
OBS3b[1]	5				
OBS4a	36	31.14	6.81	67.47	9.78
OBS4b	32	37.25	6.64	67.22	9.32
C7.1b	19	-	-	65.63	19.57
BE [1]					
O1	11	-	-	65.09	3.24
BSP	21	-	-	71.95	7.07
N1a	14	-	-	70.14	7.8
N1b	10	-	-	67.4	3.75
CS1	7	-	-	74	10.75
101[1]	1				

[1]Statistics for papers taken by fewer than 6 candidates are not included

Paper B1a: Logic

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	5.97	7.75	4.81	24	9
Q2	12.65	13.05	5.94	22	1
Q3	15.11	15.11	4.53	45	0

Paper B1b: Set Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	18.5	18.5	3.8	46	0
Q2	14.88	15.41	6.09	37	3
Q3	18.5	19.54	6.55	13	1

Paper B2a: Introduction to Representation Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	15.28	15.28	4.36	18	0
Q2	15.37	15.37	3.44	19	0
Q3	18.5	19.47	5.37	17	1

Paper B2b: Group Theory and an Introduction to Character Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	8.8	8.79	4.36	14	1
Q2	10.08	11.91	8.88	11	2
Q3	14.55	15.32	7.19	19	1

Paper B3a: Geometry of Surfaces

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	21.18	21.18	2.75	11	0
Q2	22	22	4.66	9	0
Q3	20.6	24	7.8	4	1

Paper B3b: Algebraic Curves

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	14.71	16.58	6.04	12	2
Q2	15.29	15.38	5.68	13	1
Q3	17.27	17.27	6.28	11	0

Paper B3.1a: Topology and Groups

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	18.15	18.15	3.89	13	0
Q2	17.5	17.5	3.83	16	0
Q3	18.33	20.8	6.22	5	1

Paper B4a: Banach Spaces

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	14.5	14.5	2.76	28	0
Q2	18.5	18.78	5.6	23	1
Q3	18.08	18.08	2.98	39	0

Paper B4b: Hilbert Spaces

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.52	17.52	4.02	31	0
Q2	13.87	14.5	4.32	26	4
Q3	15.54	17	6.66	21	3

Paper B5a: Techniques of Applied Mathematics

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	20.55	20.55	4.06	95	0
Q2	12.21	12.44	5.76	88	2
Q3	11.86	17.11	8.6	9	5

Paper B5b: Applied PDEs

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.63	17.99	4.48	77	3
Q2	14.57	16.07	5.88	29	8
Q3	19.37	19.37	4.97	75	0

Paper B5.1a: Dynamics and Energy Minimization

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17	17	2.56	8	0
Q2	17.5	17.5	3.78	8	0
Q3	-	-	-	-	-

Paper B6a: Viscous Flow

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	11.64	11.82	5.4	57	1
Q2	13.13	13.13	4.92	47	0
Q3	15.58	15.58	5.15	52	0

Paper B6b: Waves and Compressible Flow

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.81	17.11	4.74	35	1
Q2	15.52	15.52	4.67	69	0
Q3	15.15	15.48	5.72	40	1

Paper B7.1a: Quantum Mechanics

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	9.97	10.17	3.81	30	1
Q2	12.09	13.15	6.22	39	5
Q3	14.62	14.93	5.73	41	1

Paper B7.2b: Special Relativity and Electromagnetism

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	18.52	18.52	4.63	29	0
Q2	11.96	11.96	5.98	26	0
Q3	10.67	10.67	2.08	3	0

Paper B8a: Mathematical Ecology and Biology

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	14.65	15.13	5.46	71	3
Q2	12.87	14.81	6.79	32	7
Q3	13.38	13.91	5.68	65	4

Paper B8b: Nonlinear Systems

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	13.76	13.76	3.03	37	0
Q2	11.88	12.03	4.45	33	1
Q3	11.78	13.25	5.45	8	1

Paper B9a: Galois Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	20.34	20.34	3.80	35	0
Q2	20.41	20.76	4.02	21	1
Q3	16.11	16.11	5.23	18	0

Paper B9b: Algebraic Number Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	14.88	14.43	2.80	7	1
Q2	21.04	21.04	3.01	27	0
Q3	19.45	19.45	5.23	22	0

Paper B10a: Martingales through Measure Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.12	17.12	2.98	25	0
Q2	16.52	16.52	4.48	23	0
Q3	14.42	14.42	3.87	12	0

Paper B10b: Mathematical Models of Financial Derivatives

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	10.23	10.65	5.01	37	3
Q2	13.59	14.87	6.22	44	5
Q3	16.27	16.27	5.72	26	0

Paper B11a: Communication Theory

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	12.48	12.48	4.34	21	0
Q2	15.78	15.78	3.21	27	0
Q3	16.63	21.17	9.15	6	2

Paper B21a: Numerical Solution of Differential Equations I

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.13	16.13	3.59	30	0
Q2	14.22	16.68	7.60	22	5
Q3	18.53	19.5	5.46	14	1

Paper B21b: Numerical Solution of Differential Equations II

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.71	18.3	5.46	20	1
Q2	17	16.95	5.33	19	1
Q3	19.08	19.91	3.68	11	2

Paper B22a: Integer Programming

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	13.36	15.44	7.19	9	2
Q2	16.69	16.69	7.09	13	0
Q3	12.2	12.2	4.71	10	0

Paper B12a/OBS3a: Applied Probability

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	16.43	16.71	4	45	2
Q2	17.73	17.73	3.49	40	0
Q3	16.77	17.67	5.86	12	1

Paper OBS4a: Actuarial Science I

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.17	17.17	3.87	35	0
Q2	13.14	13.67	3.55	27	2
Q3	14.82	15.1	4.75	10	1

Paper OBS4b: Actuarial Science II

Question	Mean Mark		Std Dev	Number of Attempts	
	All	Used		Used	Unused
Q1	17.26	17.88	4.93	24	3
Q2	18.92	21.86	7.19	21	4
Q3	15.14	16	5.37	19	3

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 Candidates had difficulties adjusting to the slightly new system $K'(\mathcal{L})$, though every part was correctly answered by at least 2 students.

Question 2 contained a fair amount of bookwork.

Nobody managed to do part (c)(iii) fully, though 2 candidates got the right idea (introduce a new constant and look at non-standard arithmetic).

Question 3 Most made a good start (on propositional logic). Parts (c)(iii) and (iv), especially (iv)(γ) were only properly solved by 3–4 candidates.

B1b: Set Theory

Question 1 Part (a) was generally well done, though most people did not exhibit the specific sets that failed Foundation in (iv), (v) and did not receive full marks. In (b), there were very few problems with Tarski/Sschroeder–Bernstein. Part (b)(ii) was very mixed, with many students failing to correctly compute/simplify the cardinalities, quoting incorrect results or insufficiently general forms of Cantor's theorem.

Question 2 Part (a) was well done, though transitivity in (iv) caused some confusion. In (b), Replacement was mostly correctly stated. Part (ii) was mixed, with many students attempting to use Replacement instead of Comprehension. Part (c) was also mixed. There were two correct approaches to part (i), via Replacement and via Hartogs's Lemma. There were less problems with (ii), as students simply worked with the definition from (a)(iii).

Question 3 Fewer students attempted this problem. Students generally knew the axioms, and many had no difficulty with the proof (done in a problem set) that ZL implies AC. There were no problems defining ordinal addition. The inductive proofs were mostly quite well done. Some of the inductions were not clearly set up, and some went astray where students tried to induct on the "wrong" variable. The last question was generally well done.

B2a: Introduction to Representation Theory

Question 1 There were no problems with the bookwork (a)(i). The easy application of bookwork (a)(ii) had often surprisingly long proofs, but generally solutions were fine. In (b)(i) often students had the correct answer, but failed to check the relations to check that one has indeed a representation. The answers in (b)(ii) often were correct, but the argumentation patchy and in parts wrong. There were very few solutions for (b)(iii), however those students who solved this part, found short and clever arguments to solve it.

Question 2 The bookwork in part (a) generally was fine, with in parts too sketchy arguments in (a)(ii). In (b)(i) most students were able to write down a composition series, recognising that this was very closely related to work done on problem sheets; however students had problems in describing and hence classifying the simple modules. Part (b)(ii) was solved only by very few students, with some students wrongly thinking that the algebra must be a sum of the four simple composition factors found in their composition series in (b)(i), and some students guessing the correct answer without giving any reasons.

Question 3 Students displayed an impressive knowledge of a difficult piece of bookwork, with only smaller problems or gaps in the first claim in (a)(iii). While most students got a start for part (b), there were very few students that solved part (b) fully.

B2b: Group Theory and an Introduction to Character Theory

The overall standard was disappointing. As will be seen from the detailed comments, a few candidates had clearly paid attention to details covered in lectures, but more widely a serious price seems to have been paid for splitting the Final Honour School into Parts A and B, akin to the problems with modular A-levels, for those candidates who had clearly not realised the extent to which a good knowledge of Part A material is not merely a prerequisite, but actually integral to those parts of the subject that are linear (with no pun intended).

Question 1 Hardly anyone could write down the order of $GL(3,2)$ by counting ordered bases as had been seen for $GL(n,q)$ in general - several at least looked for linearly independent columns, while far too many went into a two page case by case analysis of the condition $det(A) \neq 0$. Only one candidate observed that 7 divides 168, and none used that to see that there is a linear transformation of order 7 whose minimal polynomial has degree 3 to factorise $x^7 - 1$. Several candidates merely wrote down the factorisation over C.

Although semidirect products were covered carefully in lectures and problem sheets, only a few candidates even attempted to write down an explicit example of a group of order 56 with the given property, and those that did wrote down abelian groups, thought that $SL(3,2)$ had index 3 in $GL(3,2)$, or thought that $GL(3,2)$ must have a normal subgroup of order 3. Rather, almost everyone launched into analysing groups of order 56 using Sylow's theorem, which is how to start on the uniqueness aspect.

Without that clear vision of the semidirect product of an elementary abelian group of order 8 by a cyclic group of order 7, which was the intention of part (a) leading into part (b), part (b) becomes more challenging than intended, and there were hardly any attempts of any merit to part (c). This explains the poor marks, even with the help of a generous reallocation merely to using Sylow's theorem correctly within part (b).

Question 2 Those who paid attention to lectures had no problem writing down the proof of the Thompson transfer lemma that I gave and at least understanding what the question was about, and that differentiated between the half who got a respectable mark on this question, and the half who didn't.

Question 3 Many made good progress, but then somehow got into a circular argument in the final part (for which only 5 marks had been assigned, fortunately) by assuming properties of S_4 inappropriately, thus failing to construct the group as a semidirect product (which, given the outcome of Question 1, perhaps in retrospect isn't surprising).

B3a: Geometry of Surfaces

Question 1 was the question that most candidates tried to solve. Although all the students seemed to have had the right ideas, most of them omitted fundamental hypothesis.

Question 2 required a proof of a well-known theorem. Most students were able to carry out the proof successfully, modulo certain details.

Question 3 There were several attempts at solving Question 3. A couple of them were successful. All the students did show understanding of the material.

B3b Algebraic Curves

Question 1 Candidates generally managed (a) and the first part of (b). For the second part of (b), many candidates took their expression for solutions $[x, y, z]$ of $x^2 + 2y^2 = 3z^2$, with x, y, z functions of integers p, q (say) from the first part, incorrectly set $z = 1$, and then found few or no solutions; whereas they should instead pass to $[x/z, y/z, 1]$. Only one candidate solved (c) correctly (set $x = a/c$, $y = b/c$ for coprime integers a, b, c with $a^2 + 2b^2 = 5c^2$ and reduce modulo 5).

Question 2 The last part of this question ("Find all the points of inflection ...") was generally badly done. Most candidates got lost in the algebra at some point and gave up. A depressingly large proportion of candidates assumed $A^3 = B^3$ in □ implies $A = B$, without considering $A = \omega B$ and $A = \omega^2 B$ for $\omega^3 = 1$, and so ended up with only one third as many points of inflection as they should have found.

Question 3 B3 questions on Riemann–Roch are traditionally horrible, but this is (I think) an exception, and fairly straightforward for candidates (the minority) that knew their bookwork really well.

B3.1a Topology and Groups

Question 1 was on the fundamental group (definition of the simplicial version and calculation). Most students did well with parts (a) and (b).

Students often gave a different proof from the notes for the fundamental group of the sphere and some did not explain very clearly how they use the winding number for the calculation of the fundamental group of the circle. Part (c) was done well. Some candidates did not manage to write down the correct formula for the homotopy equivalence in part (d). The last part was the most challenging one but a few managed to do this as well and some 'guessed' the right result and got some partial credit for this.

Question 2 was more algebraic: on presentations, push outs, subgroups of free groups and applications to homotopy equivalences. Many students had trouble with part (a) even though it was done in classes. The first part of (b) was well done but no one thought to take a homomorphism to $\mathbb{Z}$ for the second part and few students managed to do this. Some managed to prove this using the presentation but most students who argued using presentations gave incomplete proofs. Parts (c) and (d) were done by most students and part (e) was done by quite a few students following the hint given. Part (f) was bookwork and was done by many students and part (g) was an application of the earlier parts so it was done by most students who followed this through. Part (h) was similar to (g) but many candidates failed to see that they had to invoke the Nielsen–Schreier theorem and gave incomplete answers.

Question 3 was on covering spaces. Part (a) was bookwork and was generally well done. Some candidates gave incomplete answers in (iv) as they did not see that part (iii) (or a similar argument) had to be used for this. Part (b) was a bit more challenging and some students gave the covering spaces but failed to show that they are not homeomorphic- or assumed that non-isomorphic graphs are not homeomorphic which is not quite correct. Part (c) was the most challenging part but quite a few students managed to do this as well.

B4a: Banach Spaces

Question 1 The main theme of the question did not appear in Exams recently, although the topic (closedness of direct sums) is very present in the lectures and on a problem sheet. This year it was even mentioned more and related to several concepts. Anyhow, the question seemed not as popular as question 1 used to be.

Students did quite well on the bookwork part, although sometimes the domain of definition of the canonical projection was confused. The last bit, asking for specific examples, caused considerable difficulties – often due to lacking expertise about convergence of a series, rooted in Mods.

Question 2 The popularity of this question met with the expectations, and the huge majority of the students showed a good and reliable knowledge of basic applications of the Hahn–Banach theorem. The question had a last part, which could be solved in a way used in the previous years but also allowed considerable shortcuts. Unfortunately, only very few students found them but altogether the question was quite successfully treated by most of the candidates. Hopefully, in the preparation for the next exams students will develop their sensitivity for alternative solutions.

Question 3 For a question about spectral theory this question was unusually popular, and overall I was quite pleased by the solutions. In particular for the non-standard but easier part students found several solutions, though rarely optimal, always demonstrating a good understanding of the subject. Many students successfully addressed the easier half of the last part, sometimes a disturbing lack of precision when handling the Lebesgue integral showed up. The very last part was indeed quite hard (but reminiscent to some older exam questions), but several students presented very nice solutions.

B4b: Hilbert Spaces

There were many very competent scripts, with just a few very high marks and hardly any very low ones.

Question 1 This worked as intended, although the marks were quite closely bunched. Some candidates were defeated by the tricky bookwork that (b) implies (a), but they were able to continue with the question. Part (iii) was standard material from Part A and worth only one mark, but a number of solutions were laborious. Part (iv) and the final task were not easy. Quite a few attempts included the convenient, but fallacious, assertion that Ran(I-S) is closed, thereby missing the point of the early parts of the question.

Question 2 did not work as intended, because most candidates found (i) and (ii) difficult despite having seen similar examples. Unfortunately failure on (ii) blocked progress on (iii) and (iv). These parts were marked generously, but it would have been better to have set (ii) in a different way.

Question 3 worked as intended, with a wide spread of marks. Part (iv) needed a small leap of imagination or insight.

B5a: Techniques of Applied Mathematics

The first two questions were the most popular (by far).

Question 1 This question was done with good success by a large portion of the candidates. As such, it fulfilled its purpose as a predictable entry question that was similar in spirit to problem sheet questions on Green's function and to question in exam papers from previous years. Most students seem to have practised Green's function calculations and the basics of distributions thoroughly, including, in the former case, the necessary algebra, so many got most of their answers right.

Question 2 Candidates struggled more with this question, despite similarities to previous exam papers. Some attacked the question by (wrongly) assuming the kernel was degenerate. Others got lost in the extensive but straightforward algebra required to show the given eigenvalues/functions were in fact eigensolutions. Others did not know how to use the information to discuss solvability (via Fredholm alternative).

Question 3 Few candidates attempted this question seriously, but those who did did get major parts of the question answered correctly, in particular a good portion of the first part on the singular points of DEs. Only very few candidates got through the question completely and correctly.

B5b: Applied PDEs

Question 1 Most candidates performed well on this question, although few were able to determine the domain of definition for (a,iii) or to explain clearly why $u+ < u-$ for a causal shock. In response to a query raised during the exam, all candidates were informed that u+ and u- were assumed positive and constant. This query (and its clarification) did not appear to have adversely affected the candidates.

Question 2 Most candidates produced complete solutions to the standard bookwork for part (a). In part (b) [which contained an unannounced typo] credit was given to candidates for: (i) correctly defining the Riemann function, (ii) making the stated transformation or a reasonable attempt to determine the Riemann function, (iii) using the result from part (a) to obtain the stated solution.

Question 3 Most candidates who attempted this question were able to prove the maximum principle and uniqueness of solutions to the Dirichlet problem, in spite of the typo in (a,ii) where $f(x, t, U)$ should have read $f(x, t)$. In part (b), most candidates were able to show invariance of solutions and to obtain the stated ODE for the similarity variable.

B5.1a: Dynamics and Energy Minimization

Question 1 All 8 candidates attempted this question. Although there was no complete solution (no-one succeeded in doing the last part (vi)) there was one very good attempt and 5 reasonable answers.

Question 2 All 8 candidates attempted this question. There was no complete solution, but 3 very good and 2 reasonable attempts. No-one succeeded in doing the last part (g)(ii).

Question 3 There were no attempts at this question, which was on the harder material at the end of the course.

This is a challenging course, with elements of topology, analysis, dynamical systems, functional analysis, the calculus of variations and partial differential equations. Taking this into account the overall performance was quite good.

B6a: Viscous Flow

Question 1 was attempted by about 75% of candidates. The bookwork and tail were found harder than expected. The majority of candidates carelessly dropped marks for incomplete statements of the definitions and theorems requested in (a)(i) and failed to show that the stress tensor is symmetric in (a)(ii). The first half of the bookwork in (a)(iii) was poorly reproduced from a problem sheet question, while the second half was answered correctly by almost all candidates. The derivation of the diffusion equation in (b)(i) was also done poorly on the whole: only a handful of candidates showed that the pressure gradient is spatially uniform, before applying correctly the condition that there is no applied pressure gradient. Despite being very similar to a problem sheet question, (b)(ii) was answered woefully by the majority of candidates, many of whom failed to solve a linear second-order ODE with constant coefficients. A small minority made progress on the tail in part (b)(iii).

Question 2 was attempted by about 60% of candidates. The bookwork and tail were found a bit harder than expected. The majority of candidates carelessly dropped marks for incomplete justifications of the dominant balance argument or of the boundary conditions in the bookwork on boundary layers in (a)(i). The far-field analysis in (a)(ii) was well done on the whole, though a significant minority failed to use both of the conditions given in the question. The use of the chain rule stumped all but a handful of candidates in (b)(i), but not in (b)(ii). There were many good attempts at the tail, but none scored full marks.

Question 3 was attempted by about 65% of candidates. The bookwork in (a)(i) was answered almost perfectly by those that had learnt it, though many of those that had not got there eventually anyway. Despite (a)(ii) being closely based on a problem sheet question, it was answered poorly. Part (b) was perhaps a little too easy, being very well done on the whole. A number of candidates carelessly dropped marks for incomplete justifications of the lubrication approximation or of the boundary conditions in (b)(i), and for applying incorrectly Leibniz's rule in (b)(ii): all but a handful failed to spot that it wasn't even required, the thickness of the fluid layer being spatially uniform.

B6b: Waves and Compressible Flow

Question 1 was well done, especially since some aspects of it were less familiar to candidates. Part (a) was largely done well, though it revealed some carelessness with the use of the summation convention, such as triply (or more) repeated indices. In part (b)(ii) relatively few candidates noticed that since $c_p^2 > c_s^2$ and $k^2 - \omega^2/c_s^2 > 0$ was assumed, then $k^2 - \omega^2/c_p^2 > 0$ also. However, this did not hold candidates up unduly. Very few candidates were able correctly to determine the linear relationship implied by the stress conditions in (b)(iii). None realised that the waves are, in fact, non-dispersive since dividing through the dispersion relation by k^4 yields a single equation for $c = \omega/k$ with no dependence on k; many seemed to think that the relevant wave speeds were c_s and c_p, which are actually material constants.

Question 2 was generally done to a satisfactory level, although large parts should have been familiar from a question on the problem sheets. In part (b) the main issue encountered was carelessness in the choice of the constant in Bernoulli's equation. In (c)(i) very few candidates realised that the waves from (b)(ii) needed to be superposed (analogously to Fourier series) to give the result (after imposing the conditions at $x = 0$). Part (c)(ii) was well done on the whole, but very few realised that the expression for λ had a maximum at $s = 2$ and deduce (in (c)(iii)) that the waves are confined to a finite wedge. Only a handful were then able to do the geometry that yielded $\theta = 2\sin^{-1} 1/3$.

Question 3 Parts (a) and (b) were generally well done with the bookwork well reproduced by a large number of candidates. In part (c)(i) relatively few candidates saw that this was a simple application of the method of characteristics. Instead a number used the given solution as an ansatz and attempted to show that it was a solution. Where candidates realised that care was needed in taking the partial derivative with respect to t (and hence at constant x) this was well done. Unfortunately, a large number did not take care with this. Very few candidates made a serious attempt at part (c)(ii).

B7.1a: Quantum Mechanics and Electromagnetism

Question 1 appeared to be the hardest one. While most students completed successfully parts (a) and (b), many students didn't know the expression for the field strength for an infinite wire carrying constant current (this was seen in the lectures) for part (c), hence compromising the rest of the question, where most of the marks were allocated. The final answer to part (c) was fixed up to gauge transformations (so different candidates found different correct answers), but one form of the answer was much better in order to understand how to attack part (d). Furthermore, in part (d), many students made an incorrect use of the scalar Laplacian (trying to apply this formula to a vector). While this can be applied to the z component, it cannot be applied to the radial component of a vector.

Question 2 appeared to have the right level of difficulty. Part (b) showed to be more difficult than expected (and maybe a little bit too long), but parts (c) and (d) were independent of part (b).

Question 3 Again, this question appeared to have the right level of difficulty and I perceived it as the easiest one. Most students completed successfully parts (a) and (b) and most of part (c), and several students did some progress in part (d). In part (a), some students forgot some factors in the commutation relations. This is equivalent to set the Planck constant to some value (such as 1 or -1 or I), which would be perfectly ok if that value was real. Hence, I didn't penalize such omission.

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

In summary: Question 1 was very successful, with most candidates appearing to be comfortable with most of the question. Questions 2 and 3 seem to have been more difficult for the candidates, with Question 3 being attempted by only a few.

Question 1 All candidates attempted to answer this question. Almost all candidates picked up full marks for part (a). In part (b) some candidates lost marks for rotating spatial coordinates so that the space-like part of the 4-vector lies in the x-direction, and then performing a boost in the x-direction. This constitutes a loss of generality in their proof, as they are using the freedom in setting the x-direction twice. Some candidates also used incorrect inequality signs in their proof (usually $>$, rather than $\geqslant$). I subtracted a mark for each of these errors, if the rest of the proof was good. Part (c)(i) was generally answered well, but many candidates failed to show $g(X, Y)$ is non-negative in their proof of (c)(ii) and lost a mark for this omission. Part (d) was answered with mixed success.

Question 2 was attempted by most candidates, but generally with less success that Question 1. Part (a) was answered well by most candidates. Part (b) was also answered well, although sloppy language was used by some candidates in explaining why the quantities in the question were the same in every inertial frame of reference. I used my best judgement to determine whether they understood the basic reason (the quantity is Lorentz invariant), and awarded points on this basis. Most candidates gained some points on part (c), although some failed to explain or show why the same constant (τ_0) appears in both equations. Some also showed that these expressions are sufficient to describe a trajectory, but not that they are necessary. Candidates lost a mark for each of these omissions. Part (d) of this question seems to have been considerably more difficult for most candidates, with many failing to pick up any of the 10 marks available. A few candidates, however, provided very good answers. Due to the apparent difficulty that this part of question caused, I tried to award points for any substantive progress towards an answer. I also awarded a point for answering the final query, even if the rest of the question was answered incorrectly. Part (e) also seems to have caused problems for most candidates, with only a few gaining marks here (not always the same candidates that gained marks for part (d)).

Question 3 Only 3 candidates attempted this question. The question itself does not seem to me to be very difficult, so I can only guess that the lack of enthusiasm was due either to a lack of comfort with electromagnetism, or to the topic being covered only late in the lecture course. Part (a) was attempted successfully by these three candidates, but part (b) was not. This is surprising to me, as this part of the question was given explicitly as a worked example in the lectures. Parts (c)-(e) were not answered well, possibly due to a lack of time.

B8a: Mathematical Ecology and Biology

Question 1 This question was very popular, with almost all students attempting it. The quality of answers varied widely.

(a) Only one or two people sketched the graph to find linear stability. This was easily the easiest method. The majority could not solve the ODE correctly and did not show the link with the linear stability analysis (or consider initial conditions both above and below the non-zero steady state).

(b) Many students did not find all the steady states, and many had problems evaluating linear stability.

Question 2 This question was not particularly popular, with about a third of students attempting it. Many scored reasonably well.

(a) The first part of the question as standard bookwork. However, in (iii) many students could not justify use of the pseudo-steady state hypothesis from a biological point of view. Part (iv) was not well answered.

(b) This part was a simple extension of that seen in the lecture notes. In (iii) students should have noticed that the maximum velocity was unchanged but that the effective equilibrium constant was increased. Overall this means a decrease in reaction velocity.

Question 3 This question was attempted by about two thirds of the students, and on the whole it was poorly done.

(a) Many students did not note that the second term represented predation, which saturates for large N.

(b) A large number of students did not correctly non-dimensionalise space.

(c) This was a standard problem, covered thoroughly in the course. However, many students did not see that there was a critical value of the parameter b which represented a change from one to three non-zero steady states. The significance of $a < 1/4$ was also lost on many.

(d) Many students did not use the boundary conditions to justify the form of the spatial term, and hence did not get to the final answer.

B8b: Nonlinear Systems

Even the weakest students were able to do something, and there were some nice challenges there for the top students. This exam was, by design, a bit more challenging on the top end than last year's exam. One thing that surprised me was that very few students attempted Question 3 even though it was (in my mind) no more difficult and no more time-consuming than the other 2 questions. Indeed, the students who attempted this question seemed to perform on a level consistent with performance for the other two questions.

Question 1 Almost every student attempted this problem. I needed to give points at various times for 'propagation errors' (e.g., plots in part [b] that were correct relative to incorrect answers given in part [a]). Many students had all sorts of trouble producing correct phase portraits, even on an example that was exceptionally close to systems that were discussed explicitly. Students did ok with the basic bifurcations in part (c), though I should remark that this pitchfork is exactly one they saw. Most students had difficulty picking up on the global bifurcations, which were somewhat different from the familiar ones, and almost nobody picked up on the codimension-2 bifurcation. There was a large range in quality of answers for part (d).

Question 2 Almost every student attempted this problem. Parts (a) and (b) were mostly fine, though some students got unexpectedly confused. In retrospect, I would have used slightly different phrasing for part (a), as some students went through the details of a mathematically rigorous proof, and I was not expecting that much time to be spent on this problem part. The first part of (c) was basically fine for many students. Some of them had good answers to the second part of (c), though that was patchy, and very few students had good answers for the plot. Suprisingly, many students seemed to be unaware [from stress of exam conditions?] that "$|\exp(i * at)| = 1$" and that "$\cos(at) + i * \sin(at) = \exp(i * at)$". Some students realized that most of part (d) could be taken directly from the answer to (c), but many students did not see that. Indeed, many students submitted answers to (c) and (d) that were wildly inconsistent with each other.

Question 3 Surprisingly few students attempted this question, which was not any more difficult than the other two. The performance on this question was no worse than any of the others (as far as I can tell). Defining the Hopf bifurcation was fine for just about all of them, but only some of them got the second part of (a). Problem (b) was mostly fine for people, though some students forget to check that the quantity inside the square root is negative and others just managed to confuse themselves. Part (c) was difficult for the students, and none of them realized that one does indeed need to consider nonzero changes in J. There were a couple of good attempts at part (d)—and I suspect that it was seeing this part of the question that probably caused students to not want to try Question 3—and one student came *really* close to getting the whole thing, which is great to see for a part of a problem that is intended to be challenging. The overall quality of answers to (d) was better than those to (c).

B9a: Galois Theory

Question 1 was by far the most popular question, though the average mark was a little less than that on question 2. It was done well on the whole, though far too many candidates forgot the irreducibility requirement in the definition of a normal extension. Part (c) was straightforward for those who used (b) to show that adjoining one root of an irreducible polynomial over a finite field is enough to obtain the splitting field; others used longer approaches which were also successful.

Question 2 was well done, though many candidates approached (c) by quoting the theorem on solubility by radicals (not really a 'standard fact about soluble groups') instead of using parts (a) and (b) as intended.

Question 3 was the least popular and surprisingly poorly done in comparison with the other two questions, though there were some excellent answers.

B9b: Algebraic Number Theory

Question 1 This was answered by the fewest number of candidates. Parts (a) and (c) were from lecture notes and homework, whereas parts (b) and (d) contained significant original content. Candidates found this the most difficult question and no one was able to put together all of the different parts to obtain a complete solution.

Question 2 This was answered by almost all candidates and was closely based on results and examples in the lecture notes. Overall it was done very well although only a few candidates attained the highest marks. Some candidates confused the two theorems of Dedekind but noticed this retrospectively when they came to apply the second one.

Question 3 This was answered by a large number of candidates. Part (a) was bookwork and (b) and (c) were similar to questions from the lecture notes or problem sheets. A surprising number of candidates struggled with part (a), or incorrectly computed the Minkowski constant in part (b). On the whole the question was done very well.

B10a: Martingales Through Measure Theory

Question 1 was the most popular. The bookwork was mostly very well done, as was (b)(i). For the next part many candidates applied Kolmogorov's 0/1-law (correctly) even though direct arguments were needed (and given) for the almost sure upper and lower bounds. Almost no candidates managed the last part.

Question 2 was the next most popular. The bookwork was mostly reasonably well done, though often details were missing in (iv). Essentially all candidates managed (b)(i), but fewer the next two parts.

Question 3 was least popular and least well done. The bookwork was ok but often missing details. For part (c) surprisingly few candidates realized that part (b) (and/or a result in lectures) immediately gives a.s. convergence to something (random). Some managed to find unexpected ways to complete the question though.

B10b: Mathematical Models of Financial Derivatives

Question 1 Most students did the early (first 3) parts of this question well, correctly using the Itô formula (though some did not say that they were indeed using Itô's formula) and carrying out the replication argument (some put together a riskless portfolio of option and stock, not quite what was asked for, but acceptable if done well). Some candidates did not get the $\mathbb{Q}$-dynamics of the process correct, using the same Brownian motion W as in the question, whereas one needs a new BM ($W^{\mathbb{Q}}$, say). Even some candidates who got the notation correct did not explicitly say that the new process was a BM under the new measure.

Many candidates did not explicitly evaluate the functions with the correct random arguments, for example writing $v_x(t, x)$ for $v_x(t, S_t)$, or omitting the arguments altogether. The latter might be acceptable if a candidate notes that the arguments are omitted for brevity, but then indicates elsewhere what the arguments would be.

Very few candidates indeed did the 4th and 5th parts of the question correctly, even though the method of solving the Ornstein–Uhlenbeck SDE had appeared on a problem sheet in the course. Hence almost no-one computed the limiting value of $\mathbb{E}[S_t]$ correctly.

Question 2 was done fairly well by most candidates, and indeed was attempted by the vast majority of the candidates. A few candidates did not get the definition of predictability correct, confusing it with adaptedness or the martingale property.

Quite a substantial number of candidates made the second part of the question too complicated, invoking a long inductive argument from the lecture notes which showed the binomial model is complete, having quoted formulae (if done correctly) for the hedge portfolio and risk-neutral probabilities. All that was really needed was to show a one-step replication argument from which the formula for the hedge portfolio and risk-neutral probabilities emerge naturally. Then the one-step risk-neutral pricing formula also emerges naturally.

Many candidates did the numerical computations well, understanding the basics of a backwards recursion to compute option values. But some failed to realise that the running minimum of the stock price is ω-dependent, and set it to 1 in all states. A surprising number made basic arithmetical errors, the most common one being to set $(2/3)^2 = 4/3$. The last part, on adjusting the computation to compute the value of an American claim, was mostly done well. Most candidates noticed that the values were the same for both the European and American claims, but few linked this to the fact the option was a lookback *call*, and hardly any noticed that this was in fact an example of the standard result for call options.

Question 3 was done very well by the majority of candidates who attempted it. The last part, requiring a simple change of variable and equating two functions, could have been done more cleanly in a number of cases. Many candidates forgot to mention why the cross-variation terms were not present. Some did not justify that the formula for Z they got implied that Z was a BM, for example by invoking the Lévy criterion.

Some general comments: many candidates were guilty of reproducing verbatim some arguments from the lecture notes, when these were not required. A case in point was doing derivations for non-zero interest rates (even though rates were set to zero in the question), then setting $r = 0$ at the end. This is wasteful of time, of course.

B11a: Communication Theory

Overall, this paper worked well. Everyone found something to do, and the hard parts tested the better candidates as required.

Question 1 The average mark on this question turned out to be lower than par, because a surprisingly large number of candidates did not know the meaning of the two words 'necessary' and 'sufficient' in a mathematical context. That is to say, they supposed them to have their converse meaning in each case. There was also doubt about the interpretation of the standard notation for a product; and a belief that the truth of an example suffices to prove a general proposition.

Question 2 A lot of marks were scored, despite one or two inappropriate uses of Gibbs's inequality. But few candidates made any headway with part (c) because they could not [except for just one candidate] recall a result that they had previously seen in the Mods Probability problem sheet 4;

Question 3

This question was very well done by the majority of those who attempted it.

B21a: Numerical Solution of Differential Equations I

Question 1 Linear multistep method, including definitions, proof from lectures and unseen difficult final part. Definitions mostly correct, many unable to reproduce proof from lectures (but a number with full proof), only a few able to complete unseen final part which in retrospect may have been too difficult, despite given hint.

Question 2 Implicit ODE one step method, calculate a Lipschitz constant, bound truncation error and determine solution error bound. Very few complete solutions despite all the elements of the question coming directly from a lecture example of explicit method. General lack of precision in dealing with the four parts of the question, combined with algebraic errors, lost marks in many solutions.

Question 3 Approximation of PDE question: definitions and simple proof from lectures, application to unseen problem. A number of complete solutions, material well understood by those who answered questions and marks lost mostly through algebraic errors or not having time to complete question.

B21b: Numerical Solution of Differential Equations II

There were many good scores on this paper, which was perhaps on the easy side. All three questions were attempted by a reasonable proportion of candidates,

B22: Integer Programming

All questions were attempted in equal measure, and the spread of marks was largely similar. One student achieved full marks, and two more close to full marks. There were two outliers at the bottom. Most candidates attained marks in the usual range of 25-35 points.

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 four topics: mathematical finance (chosen by 10), temperature modeling in subduction zones (4), optimization of measles vaccination (7), and cell growth (6).

Written projects and peer reviews were double-marked by two assessors, a different pair for each topic. Oral assessments were triple-marked. The standard of the latter was high and sometimes excellent: all candidates presented well prepared material, almost all of it at the right level for a general audience.

In all cases marks were reconciled without difficulty. It was always hoped that able students could score as highly on this course as on a standard written paper, so it was pleasing to see a very good proportion of students achieving marks in the First Class range.

O1: History of Mathematics

O1 History of Mathematics is examined in two parts: an extended essay submitted at the end of HT and a written examination in TT. Each component contributes 50% to the total. Both parts are blind double-marked. For each part a USM is then agreed by a careful reconciliation procedure. In most cases the discrepancies between the two 'raw' marks were not large; reconciliation did not require reference to a third assessor.

Although the topic set for the extended essay, 'Origins of the theory of groups: aspects of the contributions of Galois, Cauchy and Cayley' was not an easy one, the standard of the submitted essays was pleasing, showing a sophisticated and intelligent understanding of the original articles and the secondary sources studied in the HT reading course.

In the written examination the short questions attracted 2, 2, 5, 1, 7, 7 answers respectively, and the longer questions had 3, 5, and 4 answers. The standard was a little disappointing. As last year, many scripts contained too many generalities, with inadequate detail and too little argument from evidence. Nevertheless, considering that the students come to this course with no background at all in the history of mathematics, and that the questions demand both knowledge and historical judgement, the scripts provided plenty of evidence that the candidates had learned a considerable amount and engaged properly with the subject.

Marks (in USM format) on the extended essay ranged from 61 up to 78; marks on the examination paper ranged from 59 to 70; when combined they produced final USMs ranging from 62 to 71. Although at the top end these are lower than had been hoped and expected, generally they are consistent with the students' performance (as a group) in classes and seminars.

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 again 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. Some of the work was outstanding and nearly all indicated capability to work at M level in educational studies. Weaker work failed to synthesise ideas from the literature to provide strong arguments. Nine candidates achieved over 70%; six between 60% and 70%. One candidate failed to achieve over 60% on any component and perhaps it had not been the right choice as it requires considerably different study skills to those used in mathematics courses. We are delighted that so many students stayed with the course this year - we only lost one.

N1b: Undergraduate Ambassadors Scheme

The assessment of the course is based on:

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

The journal and report were double-marked. The presentation was assessed by a single assessor. 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

OCS4a: Reasoning about Information Update

Philosophy Options

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

101: History of Philosophy from Descartes to Kant

F. Comments on performance of identifiable individuals

Removed from public version.

G. Names of members of the Board of Examiners

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  Dr E Gaffney
  Prof. I Gordon (External)
  Prof. J Lister (External)
  Dr A Muench
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