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

November 12, 2013

Part I

A. STATISTICS

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

  See Table 1, page 1.

- **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 C.

- **Marking of scripts.**
  The whole unit dissertations and half unit dissertations were double marked. The remaining scripts were all single marked according to a pre-agreed marking scheme which was very closely adhered to. For details of the extensive checking process, see Part II, Section A.

- **Numbers taking each paper.**
  See Table 5 on page 7.

Table 1: Numbers in each class

	Number					Percentages %				
	2013	(2012)	(2011)	(2010)	(2009)	2013	(2012)	(2011)	(2010)	(2009)
I	56	(45)	(47)	(49)	(48)	47.46	(45.45)	(46.53)	(46.23)	(50.53)
II.1	41	(36)	(37)	(37)	(30)	34.75	(36.36)	(36.63)	(34.91)	(31.58)
II.2	15	(15)	(14)	(15)	(13)	12.71	(15.15)	(13.86)	(14.15)	(13.68)
III	4	(3)	(1)	(5)	(3)	3.39	(3.03)	(0.99)	(4.72)	(3.16)
F	2	(0)	(2)	(0)	(1)	1.69	(0)	(1.98)	(0)	(1.05)
Total	118	(99)	(101)	(106)	(95)	100	(100)	(100)	(100)	(100)

B. New examining methods and procedures

None.

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 26th February 2013 and the second notice on the 29th April 2013.

These can be found at https://www.maths.ox.ac.uk/notices/undergrad/2012-13/part-c, and contain details of the examinations and assessments. All notices and the examination conventions for 2013 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 thank in particular Vicky Archibald, Helen Lowe, Waldemar Schlackow and Charlotte Turner-Smith for their commitment and dedication in running the examinations systems. We would also like to thank Nia Roderick and Sandy Patel for all their work during the busy exam period. We also thank the assessors for their prompt setting of questions and for the care in checking their own and the other half unit. All the assessors and the internal examiners would like to thank the external examiners Professor Jack Carr and Professor Andrew Thomason for their prompt and careful reading of the draft papers and insightful comments throughout the year.

Timetable

The examinations began on Monday 29th May and finished on Monday 10th June.

Medical certificates and other special circumstances

The examiners were presented with medical notes for eight candidates.

Setting and checking of papers and marks processing

As is our usual practice, the questions were initially set by the course lecturer, with the lecturer of the corresponding half unit and the Subject Panel Convenor involved as checkers before the first draft of the questions was presented to the examiners. The course lecturers also acted as assessors, marking the questions on their course(s).

The internal examiners met in early January to consider the questions on Michaelmas term courses, and changes and corrections were agreed with the lecturers. The revised questions were then sent to the external examiners. Feedback from external examiners was given to examiners and the relevant assessor for each paper who responded to the internal examiners for their next meeting. Internal examiners met a second time to consider the external examiners' comments and the assessor responses making further changes as necessary before finalising the questions. The same cycle was repeated towards the end of Hilary term for the Hilary term courses, although the schedule here was much tighter. Following the preparation of the Camera Ready Copy, each assessor signed off their paper in time for submission to Examination schools in week 1 of Trinity term.

A team of graduate checkers, under the supervision of Vicky Archibald, 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 a number of errors were corrected, each change was signed by one of the examiners who were present throughout the process. A check-sum is also carried out to ensure that marks entered into the database are correctly read and transposed from the marks sheets.

Determination of University Standardised Marks

The Mathematics Teaching Committee issued each examination board with broad guidelines on the proportion of candidates that might be expected in each class. This was based on the average in each class over the last four years, together with recent historic data for Part C, the MPLS Divisional averages, and the distribution of classifications achieved by the same group of students at Part B. The classifications awarded at Part C broadly reflect the overall distribution of classifications which had been achieved the previous year by the same students.

Table 2 on page 4 gives the final positions of the corners of the piecewise linear maps used to determine USMs from raw marks. For each paper, P_1, P_2, P_3 are the (possibly adjusted) positions of the corners above, which together with the end points $(100, 100)$ and $(0, 0)$ determine the piecewise linear map raw $\to$ USM. The entries N_1, N_2, N_3 give the number of incoming firsts, II.1s, and II.2s and below respectively from Part B for that paper, which are used by the algorithm to determine the positions of P_1, P_2, P_3.

Table 2: Position of corners of piecewise linear function

Paper	P_1	P_2	P_3	Additional corners	N_1	N_2	N_3
C1.1a	(13.39, 37)	(23.3, 57)	(45, 70)		4	4	1
C1.1b	(8.39, 37)	(20, 48)	(33, 67)	(41.6, 72)	2	2	0
C1.2a	(12.01, 37)	(20.9, 57)	(31.4, 72)		7	7	3
C1.2b	(12, 35)	(19.4, 57)	(37.4, 72)		6	3	3
C2.1a	(13.56, 37)	(23.6, 57)	(35.6, 72)		5	2	0
C2.1b					4	1	0
C2.2a	(11.2, 37)	(23, 57)	(42, 72)		10	4	0
C2.2b	(17.06, 37)	(29.7, 57)	(43, 72)		4	3	0
C2.3b	(13.61, 37)	(23.7, 57)	(28, 72)		4	1	0
C3.1a	(14.36, 37)	(25, 57)	(40, 72)		6	2	0
C3.1b	(12, 34)	(27.6, 72)			5	2	0
C3.2b	(17, 40)	(33, 66)	(40.6, 72)		3	2	0
C3.3b	(10.69, 37)	(21, 56)	(30.6, 72)		4	2	0
C3.4a	(18.56, 37)	(32.3, 57)	(40, 71)		0	2	0
C3.4b	(22.69, 37)	(41, 65)	(47, 72)		5	1	0
C4.1a	(17, 48)	(20, 57)	(31, 72)		10	2	1
C4.1b	(14, 37)	(34.2, 72)			8	1	1
C5.1a	(6, 20)	(7.93, 37)	(21. 57)	(34.8, 72)	7	4	0
C5.1b	(18.56, 37)	(32.3, 57)	(36, 72)		3	1	0
C5.2b					2	0	0
C6.1a	(14, 37)	(28, 57)	(39, 70)		4	11	3
C6.1b	(10.1, 37)	(18, 49)	(25, 57)	(37, 72)	4	6	3
C6.2a					1	2	1
C6.3a	(15, 37)	(22, 57)	(41, 70)		11	31	6
C6.3b	(16, 37)	(22, 57)	(38.8, 72)		11	19	3
C6.4a	(16.03,37)	(27.9, 57)	(38.4, 72)		12	18	5
C6.4b	(12.52, 37)	(21.8, 57)	(42.8, 72)		7	15	3
C7.1b	(14.82, 37)	(25.8, 57)	(38, 70)		1	3	1
C7.2a					3	1	2
C7.2b					1	1	2
C8.1a	(13.04, 37)	(22.7, 57)	(39.2, 72)		6	15	6
C8.1b	(13.56, 37)	(23.6, 57)	(35.6, 72)		7	20	7
C9.1a	(21.6, 37)	(37.6, 57)	(42, 70)		5	3	1
C9.1b	(16.2, 37)	(28.2, 57)	(37.2, 72)		10	4	1
C10.1a	(16, 37)	(21, 57)	(37, 70)		5	14	0
C10.1b	(9, 25)	(19, 57)	(42.6, 72)		3	5	0
C11.1a	(17, 52)	(17.9, 57)	(43.4, 72)		17	40	9
C11.1b	(10.23, 37)	(22, 57)	(43.4, 72)		11	26	5
C12.1a	(12, 37)	(22, 57)	(40.2, 72)		5	9	3
C12.1b	(13, 39)	(18, 50)	(30, 70)		5	9	3
C12.2b	(14.65, 37)	(25.5, 57)	(45, 70)		12	18	5
C12.3b	(9.54, 37)	(22, 55)	(43.6, 72)		3	9	1
MS1b	(35, 60)				0	0	0
MS2b	(18.38, 37)	(32, 57)	(41, 72)		4	3	0
MS5a	(12, 37)	(20, 57)	(35, 70)		3	9	1
MS6b	(18.21, 37)	(31.7, 57)	(39, 70)		1	8	2

Table 3: Percentile table for overall USMs

Av USM	Rank	Candidates with this USM or above	%
95	1	1	0.85
92	2	2	1.69
91	3	3	2.54
89	4	5	4.24
88	6	6	5.08
86	7	7	5.93
85	8	8	6.78
84	9	11	9.32
83	12	12	10.17
82	13	13	11.02
81	14	14	11.86
80	15	16	13.56
79	17	19	16.1
78	20	26	22.03
77	27	31	26.27
75	32	36	30.51
74	37	38	32.2
73	39	41	34.75
72	42	49	41.53
71	50	55	46.61
70	56	56	47.46
69	57	60	50.85
68	61	62	52.54
67	63	66	55.93
66	67	73	61.86
65	74	79	66.95
64	80	81	68.64
63	82	86	72.88
62	87	89	75.42
61	90	90	76.27
60	91	97	82.2
59	98	100	84.75
57	101	104	88.14
56	105	107	90.68
55	108	109	92.37
52	110	110	93.22
51	111	111	94.07
50	112	112	94.92
48	113	113	95.76
47	114	114	96.61
46	115	115	97.46
44	116	116	98.31
34	117	117	99.15
26	118	118	100

Table 4: Breakdown of results by gender

Class	Total		Male		Female	
	Number	%	Number	%	Number	%
I	56	47.46	41	46.07	15	51.72
II.1	41	34.75	35	39.33	7	20.69
II.2	15	12.71	8	8.99	7	24.14
III	4	3.39	3	3.37	1	3.45
F	2	1.69	2	2.25	0	0
Total	118	100	89	100	29	100

Table 3 on page 5 gives the rank of candidates and the number and percentage of candidates attaining this or a greater (weighted) average USM.

B. Breakdown of the results by gender

Table 4, on page 6 shows the performances of candidates broken down by gender.

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

Table 5: Numbers taking each paper

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
C1.1a	9	40.44	11.57	74.89	19.11
C1.1b	4				
C1.2a	23	31.04	7.11	71.17	11.23
C1.2b	17	32.06	10.97	69.35	15.62
C2.1a	7	37	7.57	76.57	12.19
C2.1b	5				
C2.2a	14	38.57	7.83	72.93	10.63
C2.2b	7	43	6.14	78.57	15.58
C2.3b	5				
C3.1a	8	41.88	6.85	80.88	12.73
C3.2b	5				
C3.3b	6	33.33	9.33	75.33	14.26
C3.4a	2				
C3.4b	6	47.5	3.51	86.33	14.88
C4.1a	13	32	8.83	73.23	13.43
C5.1a	12	33.5	14.57	72.83	23.97
C5.1b	4				
C5.2b	2				
C6.1a	18	31.17	11.44	62.28	19.59
C6.1b	13	29.85	7.85	63.77	10.76
C6.2a	4				
C6.3a	48	33.67	8.09	65	8.82
C6.3b	33	31.55	7.22	65	10.57
C6.4a	35	34.86	6.28	67.77	10.76
C6.4b	26	32.85	11.11	64.77	17.25
C7.1b	5				
C7.2a	6	35.5	7.56	71	15.11
C7.2b	4				
C8.1a	27	30.37	6.17	63.81	6.89
C8.1b	35	29.14	6.45	63.6	9.87
C9.1a	9	43.44	10.25	81.33	23.23
C9.1b	15	37.07	8.54	73.07	16.33
C10.1a	19	32.47	6.47	68.05	8.13
C10.1b	8	31.38	11.26	63.38	17.78
C11.1a	48	33.88	10.3	67.48	13.8
C11.1b	27	35.78	8.87	68.26	10.23
C12.1a	31	28.26	9.99	60.97	14.15
C12.1b	19	23.32	10.48	56.89	20.82
C12.2b	37	37.3	11.84	67.05	19.17
C12.3b	13	31.62	8.86	63.62	10.32
C7.4	4				

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
MS1b	3				
MS2a	3				
MS2b	4				
MS5a	4				
MS6b	2				
Half Unit CD	3				
CD Dissertation	22	-	-	73.27	9.28
OD Dissertation	1				

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

Paper C1.1a: Model Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	11.67	16.5	8.04	2	4
Q2	20.14	20.14	6.96	7	0
Q3	21.11	21.11	6.62	9	0

Paper C1.2a: Analytic Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.47	16.47	3.92	15	0
Q2	16.18	16.18	4.42	11	0
Q3	14.45	14.45	3.87	20	0

Paper C1.2b: Axiomatic Set Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13.89	15.37	5.30	8	1
Q2	17	17.8	4.92	10	1
Q3	15.25	15.25	7.76	16	0

Paper C2.1a: Lie Algebras

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.67	15.67	5.31	6	0
Q2	19.5	19.5	0.71	2	0
Q3	21	21	3.35	6	0

Paper C2.2a: Commutative Algebra

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.89	18.5	4.88	6	3
Q2	17.33	17.33	5.77	9	0
Q3	21	21	4.41	13	0

Paper C2.2b: Homological Algebra

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.25	16.25	3.95	4	0
Q2	24	24	2	6	0
Q3	23	23	2.83	4	0

Paper C3.1a: Algebraic Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	20.67	20.67	3.98	6	0
Q2	24.33	24.33	0.58	3	0
Q3	19.71	19.71	4.15	7	0

Paper C3.3b: Differentiable Manifolds

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13	14.67	6.16	3	1
Q2	14	14	3.60	3	0
Q3	19	19	5.66	6	0

Paper C3.4b: Lie Groups

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	21.75	24.33	5.25	3	1
Q2	23.33	23.33	2.08	3	0
Q3	23.67	23.67	1.97	6	0

Paper C4.1a: Functional Analysis

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.8	14.8	3.91	10	0
Q2	17.5	17.5	5.14	12	0
Q3	10.33	14.5	8.78	4	2

Paper C5.1a: Methods of Functional Analysis for PDEs

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.27	15.27	8.76	11	0
Q2	17.42	17.42	6.57	12	0
Q3	25	25	-	1	0

Paper C6.1a: Solid Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	9.69	10.09	3.35	11	2
Q2	16.1	16.1	6.26	10	0
Q3	19.27	19.27	5.98	15	0

Paper C6.1b: Elasticity and Plasticity

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.08	17.08	5.04	13	0
Q2	13.45	13.45	3.86	11	0
Q3	7.67	9	2.31	2	1

Paper C6.3a: Perturbation Methods

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.84	16.84	3.57	44	0
Q2	9	13.22	7.47	9	5
Q3	17.58	17.58	5.18	43	0

Paper C6.3b: Applied Complex Variables

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	9.78	11.73	5.42	15	3
Q2	16.88	16.88	3.12	33	0
Q3	17.11	17.11	5.75	18	0

Paper C6.4a: Topics in Fluid Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19.16	19.16	3.31	25	0
Q2	16.22	17.17	4.76	29	2
Q3	14	15.19	5.13	16	2

Paper C6.4b: Stochastic Modelling of Biological Processes

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.83	14.83	6.00	23	0
Q2	18.21	18.21	5.56	24	0
Q3	13.5	15.2	7.20	5	1

Paper C7.2a: General Relativity I

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.67	17.67	3.21	3	0
Q2	18.33	18.33	5.13	3	0
Q3	17.5	17.5	4.13	6	0

Paper C8.1a: Mathematics of Geoscience

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.6	16.6	3.04	25	0
Q2	13.88	13.88	4.54	25	0
Q3	14.5	14.5	8.02	4	0

Paper C8.1b: Mathematical Physiology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.29	14.29	4.00	34	0
Q2	13.93	13.93	3.41	14	0
Q3	15.04	15.41	3.66	22	1

Paper C9.1a: Modular Forms

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	20.75	20.75	6.65	4	0
Q2	21.33	21	5.72	8	1
Q3	23.33	23.33	3.20	6	0

Paper C9.1b: Elliptic Curves

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.75	16.75	3.53	8	0
Q2	19.57	19.57	6.22	14	0
Q3	14.9	18.5	8.25	8	2

Paper C10.1a: Stochastic Differential Equations

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.73	15.73	1.74	11	0
Q2	17.29	17.29	5.08	17	0
Q3	12.43	15	5.69	10	4

Paper C10.1b: Brownian Motion in Complex Analysis

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13.33	13.33	4.27	6	0
Q2	17.57	17.57	8.06	7	0
Q3	16	16	5.57	3	0

Paper C11.1a: Graph Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.42	14.74	5.78	39	1
Q2	17.35	18	5.79	38	2
Q3	17.81	19.31	7.16	19	2

Paper C11.1b: Probabilistic Combinatorics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.45	17.45	4.76	20	0
Q2	14.76	15.37	4.78	16	1
Q3	19.74	20.61	6.10	18	1

Paper C12.1a: Numerical Linear Algebra

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14	14	4.32	25	0
Q2	13.61	13.61	5.85	26	0
Q3	13.43	17.2	8.09	10	4

Paper C12.1b: Continuous Optimization

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12.75	12.75	6.03	16	0
Q2	11.06	11.06	5.98	17	0
Q3	8.5	12.75	6.59	4	2

Paper C12.2b: Finite Element Methods for Partial Differential Equations

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	20	20	5.38	36	0
Q2	18.3	19.5	7.49	28	2
Q3	11.4	11.4	7.23	10	0

Paper C12.3a: Approximation of Functions

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.5	17.5	5.21	12	0
Q2	15.08	15.08	4.89	12	0
Q3	10	10	0	2	0

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

E. Comments on sections and on individual questions

The following comments were submitted by the assessors.

C1.1a: Model Theory

19 candidates took the Model Theory exam, including one candidate from the joint school of Physics and Philosophy. The number of students who attempted question 1 was 11; 14 attempted question 2 and 15 candidates attempted question 3.

Question 1 was answered very well by 4 out of 11 candidates (at least 21 marks). For those who scored less typical mistakes were in answers to problem (b) which was bookwork. These candidates failed to realise that they need to prove that the construction and notions they introduced are well-defined.

Question 2 was answered very well by 11 out of 14 candidates. This too high rate of scores is partly due to the fact that the 'unseen' problem (d) proved to be too easy for them.

Question 3 was the most popular and 11 out of 18 candidates who attempted it scored at least 21 marks. The main difficulty was in the 'unseen' problem (d) but many quickly realised how to reduce the problem to a bookwork argument.

C1.1b: Gödel's Incompleteness Theorems

Question 1 1(a) was straightforward. 1(b) was a close relative of an exercise done in lectures. 1(c), which asked for a proof of Gödel's First Incompleteness Theorem, was bookwork. 1(d) asked candidates to quote an example given in lectures. Parts 1(a) and 1(c) were moderately well done, 1(b) and 1(d) less so.

Question 2 2(a) was bookwork. Part of the point of the question was to prove that Σ_0-completeness implies Σ_1-completeness, something not appreciated by all candidates. 2(b)i was also bookwork and was generally well done; 2(b)ii was not bookwork but was also satisfactorily done. The main part of 2(c), namely the proof of Löb's Theorem, was carried out very competently. Part 2(d) proved more challenging, with many candidates not recognising that an induction on $j - i$ was necessary. Overall, the question was done extremely well.

Question 3 All parts of this question were bookwork. Its challenges were twofold: to state results precisely; and to take the right shortcuts to standard proofs (e.g. reproducing the proof given in lectures for 3(d) would have proved infeasible in the time allowed). 3(a) was straightforward bookwork, although some candidates forgot to state the interpretation of the falsum. Some candidates also assumed that the material conditional and the English 'if...then' are synonymous. 3(b) was generally well done. 3(c)i caused some difficulties: the more precise answers garnered higher marks. 3(c)ii was well-answered; some of the answers could have been more succinct. 3(c)iii could have been more precisely answered. 3(d) caused some difficulties.

C1.2a: Analytic Topology

The standard of bookwork was very high. The non-bookwork parts were harder than expected, leading to a low spread of marks, especially amongst first class candidates. Question 2 was probably best at differentiating the candidates, but was taken by the fewest.

C1.2b: Axiomatic Set Theory

This year's exam question seemed to be right in terms of difficulty.

Question 1 None of the candidates who attempted question 1 earned more than 19 marks; most were in the range of 16-19. The main difficulty was in the 'unseen' problem "prove that the addition of natural numbers is commutative". Most of the candidates had in principle the right approach to it but couldn't figure out the solution fast enough. Another problem of similar difficulty was to prove the principle of mathematical induction. This problem was definitely seen by the candidates, but they seem not to have paid enough attention to delicate issues in the proof.

Question 2 was answered very well by 6 out of 15 candidates (at least 21 marks). But many scored 17 or below. The main difficulty again was in the 'unseen' problem (d).

Question 3 was the most popular and 9 out of 24 candidates who attempted it scored at least 21 marks. The main difficulty again was in the 'unseen' problem (d).

C2.1a: Lie Algebras

Question 1 was generally well answered with candidates scoring well on most parts except the last, which turned our to be unexpectedly difficult, parhaps because candidates failed to spot that a semisimple Lie algebra is equal to its derived subalgebra.

Question 2 was the least popular, though those who attempted it scored solidly. The main difficulty was correctly computing the action of the Casimir on the Horn space.

Question 3 was, despite an omission in the question which had to be added during the exam, the best answered. Most candidates spotted the modification needed to bookwork material for part (iii) and scored well overall.

C2.1b: Representation Theory of Symmetric Groups

All five candidates had good understanding of the material of the course. They showed excellent knowledge of the bookwork, and even the more complicated bookwork. Beyond bookwork, they showed good understanding of representation theoretical concepts. As expected, there were some difficulties with the advanced parts of the questions, testing for deeper understanding, in particular Q1(d).

C2.2a Commutative Algebra

Question 1 (a) and (b) bookwork: well done. (c) no-one got it all: maybe ideas too unfamiliar? (should have been easy as arguments are very simple).

Question 3 Well done by several candidates.

C2.2b: Homological Algebra

Question 1 Standard of answers was lower than in qestions 2 and 3. The main difficulty was recalling all the details of the proofs.

Question 2 Very high standard of answers.

Question 3 High standard of answers.

C2.3b: Infinite Groups

Question 1 This was the hardest question, nobody progressed much beyond (b) and could not evaluate $f([x_1, x_2]^{X_1^a X_2^b})$

Question 2 This was the most popular question with (a), (b) and first part of (c) done in lectures/problem sheets. Sadly nobody could prove that torsion-free nilpotent group is residually p for each prime p.

Question 3 Another popular question. Several flawed arguments for part (b) arguing with dimension of solution space which was done in problem sheets over $\mathbb{F}_p$ but cannot be applied to $\mathbb{Z}$ immediately.

C3.1a: Algebraic Topology

The exam was slightly unusual in that it did not test simply some standard theorems but expected candidates to think laterally using some of the more basic concepts.

Question 1 (7 attempts) This covered very standard material only that the question required candidates to adopt the Mayer-Vietoris sequence to the setting of delta-sets. Most marks were lost at this point. Some more marks were lost for not working out carefully the delta structure of a cone. Candidates should have made it clear that they moved between simplicial and singular homology to conclude that the homology of the cone is trivial.

Question 2 (6 attempts) The first part was generally well-done though the computation of the homology of the Moore complex was often very messy, and mistakes were made when computing its cohomology. Candidates should not have used the Universal Coefficient theorem but worked out the cohomology from the dual chain complex. Unfortunately, the condition $k \neq 0$ should have been included in the question. Two candidates noticed that $k = 0$ was a special case. (There was no sign that this omission resulted in any distress or loss of marks.)

Question 3 This was generally well done though relatively few managed to do part (d).

C3.2b Geometric Group Theory

Question 1 This was a basic question about algorithmic questions in groups attempted by all candidates. Most candidates did well in the first part but some did not manage to show that there is an algorithm to determine the cardinality of a finite group. In the second part some candidates did not manage to show that every word in a free group is conjugate to a cyclically reduced word (bookwork). Several candidates did not see that one needs to apply induction for the last part.

Question 2 This was a question on amalgamated products and actions on trees. Only 2 students attempted this.

Question 3 This question was attempted by 4 students. It was on the geometric part of the course dealing with quasi-isometries and hyperbolic groups. Most students did well on the coursework part of this question. Some had trouble showing that the half-line is not quasi- isometric to the line. Nobody managed to do the last part which was more challenging.

C3.3b: Differentiable Manifolds

Question 1 Only one complete solution (very well written). Not much competence in differentiating matrices.

Question 2 Basic manipulative skills OK, but some dodgy arguments on part (d).

Question 3 The bookwork question. Most failed to explicitly link the lack of fixed points to the existence of a map to the sphere.

C3.4a: Algebraic Geometry

All candidates handed in solutions to Questions 1 and 2, and these problems went very well. In Question 1 (iv) the proof of the universality of $\alpha_\sharp$ was missing in some cases, and the students struggled with the orbit structure in (v).

In Question 2 the relatively long proof of the closeness of the image of the Veronese embedding went surprisingly well, but there was no complete argument determining the Hilbert polynomial in part (iv).

Nobody attempted Question 3.

C3.4b: Lie Groups

Question 1 was attempted by half of the candidates. The very last part was perhaps the trickiest since one needs to use the power series expression for exp of a matrix.

Question 2 was attempted by half of the candidates. Unfortunately the example at the end of 2(e) is incorrect: tori are always embedded, the example I was thinking of is a line of irrational slope in T^2 which is not embedded (but it is a line, not a torus). This was entirely my fault, so no marks were assigned for this last part of the question. This mistake, unfortunately slipped past also the checker and external examiner, but surprisingly was spotted by one candidate who proved tori were always embedded.

Question 3 All candidates attempted this question and they did very well.

C4.1a: Functional Analysis

Question 1 This question was attempted by 10 candidates, and despite being fairly straightforward no candidate got full marks. In particular parts (b) and (c)(i) caused much trouble, whereas many candidates did well on the remaining parts of the question.

Question 2 This question was the most popular and was attempted by 12 candidates. The question covers a wide spectrum of material from the course, but actually not much knowledge about Schauder bases is required to answer part (c). The most difficult part seems to have been to give an example of a compact operator whose range is not closed in the last part of (a).

Question 3 Not a popular question and only attempted by 6 candidates of whom 2 have also completed substantial parts of questions 1 and 2. Part (a) seems to have gone down well with those who tried whereas, apart from two very good attempts, the rest did not attact much attention.

C5.1a: Methods of Functional Analysis for PDEs

Question 1 has been attempted by almost all candidates. In the bookwork part, most of the difficulties were in the proof of the Gagliardo-Nirenberg inequality. Not all candidates checked that an auxiliary function is smooth enough to apply the inequality given in the hint and density arguments were sometimes incomplete. Several candidates could not state the extension theorem. The problem part was based on compactness arguments. It was understood well by all candidates but technical realization was not perfect in a number of papers.

Question 2 is about the main issue of the course and was attempted by all candidates. Several mistakes were related to the definition of the strong solution. Difficult theoretical part was to check that a certain auxiliary operator is compact. In the problem part, not all candidates observed that a weaker term containing a derivative disappears after integration by parts.

Question 3 has been attacked by a very few candidates but they have done it quite well.

C5.1b: Fixed Point Methods for Nonlinear PDEs

The candidates did quite well on this examination, whith several students very close to full marks.

Question 1 was taken by most students. Parts (a), (b), (c) and (d) were close to the lectures, and consistently answered very well. Part (e) required to show that S was convex, compact with non-empty interior. Convexity and compactness were usually well done; only one good answer to the last criterion (non-empty interiors) was given.

Question 2 was attempted by one student, who did it very well. Candidates preferred to use Schauder's fixed point together with the maximum principle instead of the constructive approach; this was a perfectly reasonable choice. A relatively similar question was treated in the course notes.

Question 3 was favoured by all students. The only major mistake was to discover a null lagrangian that wasn't there and to assume that the problem was linear, which it was not. The question was well done, and the mistakes very minor.

C5.2b: Calculus of Variations

Question 1 This question was not attempted by any candidates.

Question 2 This was attempted by all the candidates. It was clear that some important concepts such as convexity, strict convexity, global minimizer, strict global minimizer, weak local minimizer and strong local minimizer, and the characterization of a convex function had been well learnt. Part (d)(ii) was found difficult: I am happy that all the candidates got the key point to tackle it, though none of the candidates worked out (ii) perfectly.

Question 3 This was also attempted by all the candidates. It was apparent that the candidates have well understood Tonelli's existence theorem for a global minimizer and Tonelli's partial regularity theorem for a strong local minimizer; yet one of the candidates missed one condition for Tonelli's partial regularity theorem. Part (c) was found tricky: all the candidates identified the right paths to answer the question; still none of the candidates gave a perfect answer.

C6.1a: Solid Mechanics

Question 1 Students found this question more challenging than anticipated. Parts (a) and (b) were straightforward and overall well done. However, students could not do the straightforward tensorial products of 1(c). Moreover, the difference between incompressibility and isochoric deformation in part 1(d) was not understood. Computations of the stress tensor for non-diagonal deformations proved challenging.

Question 2 received a mixture of responses. Most candidates were able to use the inequalities to show constraints on the parameters (12(b)), but still many did not pose the correct boundary conditions in 2(c) which created a domino effect for the rest of the question.

Question 3 was generally well done with many top marks. Students seem to understand well the limit from nonlinear to linear elasticity but many were careless in demonstrating the number of independent parameters (part (c)). All students who attempted could derive the Navier equations (2(d)).

C6.1b: Elasticity and Plasticity

Question 1 This question was attempted by all the candidates. The opening bookwork was generally done well, although many students overcomplicated their solutions by showing "only if" as well as "if". Most were able to pose the the wave reflection problem correctly and then solve for the reflection angles and coefficients. The final part caused more difficulties. Although several students successfully calculated the parameters in the given evanescent wave field, very few gave convincing physical interpretations.

Question 2 This question was slightly less popular than question 1, and the solutions were of significantly lower quality. There were many garbled attempts at the derivation and nondimensionalisation of the beam equation. Most candidates managed to justify the choice $\delta = \epsilon^2$ and to derive the resulting weakly nonlinear equation. However, many fallacious arguments were given for the solvability condition, and not a single candidate followed the hint given. The final derivation for a slightly tilted beam defeated virtually everyone.

Question 3 This question attracted just three attempts, none of them serious. The attempts displayed a flimsy grasp of basic complex analysis (for example the relation between $\partial/\partial x$ and $\mathrm{d}/\mathrm{d}z$). No-one successfully applied the given conformal map and hence no-one managed to evaluate the displacement or stress asked for at the end of the question.

C6.2a: Statistical Mechanics

The exam was well-balanced, and all 3 problems were fair.

Question 1 Three students attempted this problem (which was a modified version of things they saw in the homework), and two of them did well. The proof of point (iii) in part (e) was easier than intended because I inadvertently gave the answer away [just about completely] in previous parts of the problem. Nobody got the last part of (e) correct, as there is another condition that must be satisfied. For some parts, the students used methods that were slightly different (and, in some cases, better) than the ones I had in the solutions.

Question 2 Three students attempted this problem. Two of them did well — in fact, one of them just missed getting every point on the problem — and one did not. There were multiple ways to go about part (d), and none of them students did it the way I wrote up the solutions. Two of them had good answers to it, though.

Question 3 Technically, all 4 students attempted this problem, but only 3 attempts were"serious". One attempt was good and one was moderate.

C6.3a: Perturbation Methods

Question 1 There was a typo in this question. In part (c), $2/\pi$ should have been $\pi/2$ (obvious since it involved substituting values into the previously derived formula in which π appears in the numerator). This was announced during the examination. As far as I could see, it had no effect on the candidates.

(a) Most candidates ignored $f(t)$ in this so lost a mark.

(b) A number of candidates simply said that certain integral components were small without showing this. Most did not see that a condition on $\mathrm{i}\psi$ was that its third derivative must be non-zero. Alarmingly, a number of candidates made a substitution that seemingly turned an integral of a complex function into a real integral. If this held, Cauchy would be out of business.

(c) It was intended that students point out the answer here was $1/2$ of (b) and that since the third derivative of $\mathrm{i}\psi$ was zero one had to go to the fourth derivative. However, many of them trudged through much of the proof of (b) once again.

Question 2 Very few candidates attempted this question. (b)(iv) No candidate spotted that from part (iii) one could motivate the correct scaling. Many thought that the hint applied to the scaling when clearly it was for the matching.

Question 3 There was a typo in this question (denominator in (b)(ii) should be a square root). This was noted before the examination and announced at the beginning.

Overall, this question was very well done.

(a) Some candidates did not realise that they needed to use the initial conditions to determine the constants in the complementary function for y_1.

(b)(ii) Very few candidates pointed out that the equation they derived was for $A(T)$ squared so, on taking the square root, one has to worry about signs.

C6.3b: Applied Complex Variables

Question 1 This question was attempted by about half of the candidates. The bookwork in part (a) and the conformal mapping in part (c) were well done. The Schwarz-Christoffel map in part (b) was done poorly: while about half of the attempts stated the correct form of the map, no candidate was able to compute the parameters stated in the question. There were a few good attempts at part (d), though no candidate was able to determine h in terms of α. The candidates found this question harder than anticipated and failed to cope with the combination of the hodograph and Schwarz-Christoffel methods.

Question 2 This question was attempted by all but one candidate. The bookwork in part (a) and the application of the Plemelj formulae in part (b) were both very well done by the majority of candidates. There were a handful of good attempts at part (c), but no candidate answered it fully.

Question 3 This question was attempted by about half of the candidates. The bookwork in part (a)(i) and the application of the Weiner-Hopf method in part (a)(ii) were well done. About half of the candidates made good progress with part (c).

C6.4a: Topics in Fluid Mechanics

Q1: This question was generally done very well with candidates able to pick up marks easily on the standard bookwork and also to deal with the unfamiliar pressure efficiently. Very few, however, were able to follow through with the parts that asked about consistency of the lubrication approximation failing to realise that the correct condition in 1.c(iv) was that $2\pi/k = \lambda \gg h_0$ while that in 1.d was $x \gg 1$.

Q2: This question was extremely popular and was, in general, well done. Two common errors were made: (i) candidates missed the fact that the temperature T is measured with respect to the temperature of the upper plate and (ii) candidates often tried to impose the (incorrect) boundary condition $u = 0$ in 2.b(ii) rather than $w = 0$. The plotting of streamlines in 2.b(v) was extremely poorly done in general with very few candidates providing satisfactory sketches.

Q3: This question was harder than anticipated. The bookwork in 3.a(i) was generally well done but again candidates struggled to implement the correct boundary condition for flow between rigid plates, namely $w = 0$, which led to problems deriving the correct dispersion relation. A large number also failed to realise that the requirement for instability in a solution $\propto \exp[-i\Omega t]$ is that $\Im(\Omega) > 0$, rather than $\Re(\Omega) > 0$. Finally, very few candidates were able to show that in the limit $H \to \infty$ the instability disappears altogether.

C6.4b: Stochastic Modelling of Biological Processes

Question 1 This question was attempted by almost all candidates, especially parts (a) and (b) where candidates applied methods described in Lectures 1 and 2 of the course. Parts (c) and (d) also made use of methods which were covered in the beginning of the course. The candidates who attempted these problems were mostly able to follow an appropriate method for deriving equations for S_{11}, S_{12} and S_{22}, but some candidates made mistakes in subsequent calculations. The last part (e) of this question was testing multiscale methods covered in Lecture 15; this was attempted by fewer candidates.

Question 2 This question was also relatively popular. Parts (a) - (d) tested material from Lectures 5 and 6. Most candidates were able to write the Fokker-Planck equation in part (a) and find the stationary distribution in part (b) by solving the stationary Fokker-Planck equation. Some candidates made small mistakes when they normalized the solution to the Fokker-Planck equation to get the stationary distribution. The last part (e) was testing material from Lecture 14 about the Metropolis-Hastings material. Fewer students attempted this.

Question 3 This question was attempted by only a few candidates. Most candidates submitted Questions 1 and 2 for evaluation. This question tested material from Lecture 9. Parts (a), (c) and (d) did not make use of the equation (1) and material from Lecctures 5 and 6 was applicable.

C7.1b: Quantum Theory and Quantum Computers

Question 1 This was a popular question and the bookwork comparing the interaction representation to the Schroedinger equation was well done. The Feynman-Dyson expansion was less well done, and many candidates lost marks on the details. Part (c) was a straightforward derivation and application of Fermi's golden rule but did catch many candidates.

Question 2 Part (a) was well done by almost all candidates. Part (b) was a straight forward application of part (a) although this did become a lengthy calculation for many. In part (c) only one candidate gave a proper account of the variational method applied to a first excited state but neverthelass, many were able to do the correct calculation.

Question 3 The majority of candidates who attempted this question got the point, and were therefore generally successful even at the novel aspects of the question. More information could have been given for (b).

C7.2a: General Relativity I

Question 1 Three candidates attempted this question. Part (a) of the question asked the students to define the weak and strong versions of the Principle of Equivalence, and most students answered this question correctly. Parts (b)-(d) had to do with the metric, proper time, and 4-acceleration of rotating observers in flat space-time. Although most students were able to carry out the calculations, some had diffculty providing a physical interpretation for their results. Part (e) asked the students to compute the metric of a spatial hypersurface and compute the circumference of a circle in this geometry. Although this was a straightforward computation, some aspects of this question may have been new to to the students, so some had slight difficulty with this part of the question.

Question 2 Three candidates attempted this question. Parts (a)-(d) asked the students to derive the geodesic deviation equation, explain its physical interpretation, and show what it reduces to in the weak-field, slow-motion limit. Much of this was bookwork and most students did well on these parts. Part (e) asked the students to solve the geodesic deviation equation in a gravitational wave background. This was new to the students, so some had difficulty with this part of the question.

Question 3 All six candidates attempted this question. In this question, the students were asked to analyze the dS and AdS spacetimes. In part (a) they were asked to determine which of these spacetimes has a horizon and to compute its location. All the students correctly pointed out that only dS has a horizon, but most had some difficulty justifying this using lightcone diagrams. In parts (b) and (c), the students were asked to analyze timelike and null geodesics in these spacetimes. Most students did well on these parts, although some had difficulty computing the radius of circular orbits in AdS and arguing that photons travel along straight lines in these spacetimes. In part (d) the students were asked to compute gravitational redshift in AdS. Although this is a straightforward calculation, some of the students did not remember to use the fact that the energy of a photon is conserved. In part (e) the students were asked to demonstrate the existence of a horizon in dS using a nonstatic metric. This was new to the students, so some had difficulty with this part of the question.

C7.2b: Relativity II

Question 1 2 attempts.

Question 2 2 attempts. Candidates could not do part (a) as they did not realize that

$\Omega = \frac{\mathrm{d}\phi}{\mathrm{d}t} = \frac{\mathrm{d}\phi/\mathrm{d}\tau}{\mathrm{d}t/\mathrm{d}\tau} = \frac{v^\phi}{V^t}$. They also missed many points in part (c).

Question 3 All 4 candidates attempted this and all answers were excellent.

C7.4 Theoretical Physics

The reports of this course may be found in the Physics examiners' report.

C8.1a: Mathematics of Geoscience

27 candidates took the exam, of whom the majority did questions 1 and 2.

Question 1 hit the right spot, with the majority having marks in the 15 to 19 range. Few had very much clue about the last part, which indicates the challenge of this course: to learn to let go of formal analytic procedures.

Question 2 25 out of 27 of the candidates did Q2 with the majority having marks in the range 10 - 15 (15 candidates). They where able to do the standard analytical procedures and physical definitions, but struggled with non-book work. Six people obtained 20 and above and clearly showed a deeper physical understanding of the material. The four remaining candidates had marks less than ten.

Question 3 was attempted by four candidates.

C8.1b: Mathematical Physiology

A pleasing performance by the candidates overall with the standard elements of all questions executed well in the majority of attempts.

Question 1 was very popular, with all but one student making an attempt. The occasional student did not appreciate that "Briefly" in 1(a)(i) meant precisely that. In the latter parts of the question, the majority of students, but certainly not all, tried to rigidly follow the travelling wave analysis of the Fitzhugh-Nagumo system, and thus were unable to accommodate the more complex structure of these Huxley-Hodgkin equations.

Question 2 In the final part, (b)(ii), estimating the timescales caused more difficulty than anticipated, and most students failed to consider whether or not u was always less than μ_3 in analysing the time evolution of the inital transient.

Question 3 The standard elements were tackled well and there were a number of serious attempts at the final part. However, all but a minority of these failed to recognise that the positive steady state, p_s, could depend on the parameter Λ, which meant that more care was often required in taking limits with respect to Λ in the presented attempts.

C9.1a: Modular Forms

Modular forms was a new course this year. The students who took the course until the end performed very well in the exam. This, at least in part must be attributed to the strength of the students.

Question 1 This involved determining the modular curve for both $\Gamma(1)$ and an index three subgroup G_3. The first half, concerning $\Gamma(1)$, was purely bookwork and the caused the candidates no problem. The second half involved working with the (mostly new) subgroup G_3 and the candidates generally performed well.

Question 2 This involved two parts. The first being bookwork (proving convergence properties of the Eisenstein series). The second part used the Fourier expansion of the Eisenstein series to prove a relationship involving the divisor function. The candidates generally performed well, however, some seemed to leave blank the second part of (b) which involved showing that $E_{2k}(z)$ converges absolutely.

Question 3 This question was bookwork, and involved proving some important properties of the Hecke operators. The candidates performed well on this question.

C9.1b: Elliptic Curves

Question 1

(a) This problem refers directly to the notes and was solved satisfactorily by essentially all students who attempted it.

(b) The problems involving cube roots appear to have been surprisingly tricky. In particular, it was rare for a student to discuss carefully the reduction to the case where a is a unit, taking valuations into account. The last subproblem, a straightforward application of Hensel's Lemma, was found easier.

(c) A good number of students struggled to discuss clearly the cases of $p = 2$ and $p = 3$, when the curve has bad reduction. Also, the statement and application of Hasse's bound for $p \geq 5$ could also have been clearer. But the solutions were broadly acceptable.

Question 2

(a),(b) These problems refer directly to the notes and were solved satisfactorily by essentially all students who attempted them.

(c) There were a good number of good solutions, some unexpected. That is, many students figured out the need to show that $P = (0, 3n)$ has infinite order, but the methods were diverse. Some showed directly that $2P$ has denominators, which involves mildly tedious algebra. One clever solution simply showed that $2P$ reduces to the origin mod 3. As might be expected, some students got confused in the course of calculations.

(d) This problem appears to have been rather difficult. Many students saw that a point P of order 4 must satisfy $2P = (0, 0)$. But many struggled with the algebraic consequences. The key is to show that a P satisfying such an equation can't be rational. One way is to simply look for lines through $(0, 0)$ that have a double intersection with the curve. Another way is to try to find conditions on the coordinates of P directly. The latter is more complicated, and only a few students succeeded in completing the argument with clarity.

Question 3

(a) This was a relatively straightforward problem. However, many students attempted to use the Nagell-Lutz theorem, which leads to more computation than reducing mod 3 and 5.

(b) This was a fairly straightforward application of the techniques introduced in the lectures and many students gave satisfactory solutions.

(c) This problem ended up being rather hard. That is, even applying the method of descent correctly, students found it hard to find the point of the dual curve that has infinite order. Nevertheless, some did. Also, some students managed to find that the rank is at most one, and gave reasons justifying it.

C10.1a: Stochastic Differential Equations

Overall The paper was slightly on the hard side with no one able to get all the way through questions 1 and 3.

Question 1 was on Brownian motion and, although all except the last part was either bookwork or taken from a problem sheet, few people were able to score well. Most people could use the reflection principle to derive the law of Brownian motion and its maximum. Statements of the CMG theorem were often just of the more general version and not for Brownian motion as asked for. Despite being from the exercise sheets few people could use the CMG theorem to find the law of Brownian motion with drift and its maximum. The final part was not attempted by many. A few could write down the integral required but no one managed to deduce the solution.

Question 2 was well done. This was largely bookwork and most students were able to demonstrate their knowledge of this topic reasonably well while there were a couple of perfect solutions.

Question 3 also proved difficult to achieve high marks. The first part was generally well done with most able to use the Ito formula. However very few could see that the Levy characterization was required again to establish parts (c) and (d). Again no one was able to get out the tricky tail.

C10.1b: Brownian Motion in Complex Analysis

The results are generally good.

Question 1 Some students lost marks in (b)(iii) for not stating the optional stopping theorem or for stating a weak version that can not be applied in this case. (c)(ii) turned out to be the most difficult; most students lost marks for applying Brownian scaling to the stopping time without scaling the starting point.

Question 2 Most students did very well on this question. Surprisingly in part (b) half of the candidates have not used the fact that they were allowed to assume without proof and gave a proof of an equivalent statement instead.

Question 3 Only 3 of 8 candidates attempted this question. Everyone gave a complete or nearly complete solutions in parts (a) and (b), only one candidate solved part (c).

C11.1a: Graph Theory

Question 1 A popular question, on connectivity. Parts (a) and (b) were mostly well done, though a few had trouble even with the definitions. The main difficulty was with part (c), and in particular in showing that there is a cycle as required (the argument needs care).

Question 2 A popular question, concerning the chromatic polynomial and acyclic orientations. Parts (a) and (b) were mostly well done. The part that caused the most problems (over all three questions) was part (c) (i), which asked the student to show a recurrence for acyclic orientations paralleling that for chromatic polynomials. There were several very good answers but many got nowhere. The rest of part (c) was often quite well done.

Question 3 A less popular question, with two quite separate parts: part (a) concerning intersecting subtrees of a tree, and part (b) concerning regularity. In part (a) almost all followed the hint, and most of these students found the question fairly straightforward. Most of those who did not follow the hint got lost. In part (b), most who attempted it did quite well, though some got lost.

C11.1b Probabilistic Combinatorics

Question 1 Part (a) was fairly standard work concerning thresholds and was generally well done. Part (b) concerned large antichains: subparts (i) and (ii) were mostly well done, subpart (iii) was done well by only a handful.

Question 2 Parts (a) and (b) were a warm up for using the Local Lemma in part (c). Most students did quite well in showing that it suffices to establish the two inequalities. The next short question "What is the limiting value .." was meant to prompt that we could replace the last factor in the two inequalities by say 2/e, thus simplifying matters. However, the limiting value was often (sadly) not known to be 1/e, and the prompt was not often taken. Most students then found the remaining computation too complicated to complete. Only a handful succeeded in completing the question.

Question 3 This question concerns Harris's Lemma and the Janson's Inequality (in its easier form). Parts (a) and (b) were done well by almost all. Part (c) asked both for an upper bound on the probability of there being no copy of K_4 (to be deduced from Janson's Inequality) and for a matching lower bound (to be deduced from Harris's Lemma). Many students found the upper bound but few gave the lower bound argument.

C12.1a : Numerical Linear Algebra

This seems to have been a reasonably successful paper with very high marks achieved on each question by at least one candidate.

Question 1 on the SVD was attempted by most candidates with many marks in the high teens. Those who were able to see how to use the SVD to obtain the polar decomposition were surprisingly few.

Question 2 on Gaussian Elimination and simple Iteration was also answered by many candidates. The most difficult part of this question appeared to be the proof that no row swaps are required when employing partial pivoting for a strictly column diagonally dominant matrix.

Question 3 was on Kylor subspace methods: either very high marks or very low marks were achieved by candidates attemting this question.

I was surprised by the number of candidates who attempted all the questions, especially since most who did this did not gain anything from spending time to attempt most parts of all questions.

C12.1b : Continuous Optimisation

Questions 1 and 2 saw a larger uptake and a bigger spread of marks than Question 3. 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.

C12.2b: Finite Element Methods for Partial Differential Equations

Question 1 This question was concerned with the weak formulation of a two-point boundary-value problem with nonhomogeneous Robin boundary conditions, and the construction and convergence analysis of a linear finite element approximation of the problem. Almost all candidates attempted the question, and most of them produced complete or almost complete answers. Some candidates did not realize that for proving the existence and uniqueness of the finite element approximation to the weak solution of the problem it suffices to check the coercivity of the bilinear form in the weak formulation, and (erroneously) attempted to use a version of Agmon's inequality that only holds in the case of a homogeneous Dirichlet boundary condition.

Question 2 This question was concerned with the a posteriori error analysis of a continuous piecewise linear finite element approximation in the case of homogeneous Neumann boundary conditions. Most of the candidates who attempted the question produced complete or almost complete answers. Some of the candidates stated the associated dual problem incorrectly, with homogenous Dirichlet boundary conditions instead of homogeneous Neumann boundary conditions, or attempted to use Poincaré's inequality in the course of bounding the H^2 seminorm of the dual solution, despite the fact that the dual solution did not satisfy a homogeneous Dirichlet boundary condition.

Question 3 The question was concerned with the construction and stability analysis of the explicit Euler finite element approximation of a second-order parabolic initial-boundary-value problem with mixed Dirichet–Neumann boundary conditions. Only a minority of the candidates attempted the question, and the quality of the answers was rather disappointing. Several candidates made an incorrect choice of the test function in the stability analysis of the method in part (c) of the question.

C12.3a Approximation of Functions

Question 1 Application of Chebyshev polynomials to approximation, aliasing, derivation and convergence of a simple quadrature formula. Bookwork parts at start answered extremely well, only a few really understood how to estimate convergence rate for the quadrature formula.

Question 2 Statement of theorem for best approximation in infinity and two norms, determination of best linear approximation for infinity and two norm, using Pade approximant and estimating convergence rate for best approximation.

Bookwork excellent, all knew how to determine best approximations, the algebraic manipulations were routine but involved and a number of weak examples, matched by a slightly larger number of accurate solutions. Only a few able to estimate convergence rate for last part of question.

Question 3 Deriving and estimating the Lebesgue constant for an Chebyshev approximation

No pattern.

Statistic Half-Units

Reports of the following courses may be found in the Mathematics and Statistics examiners' report.

MS1b: Statistical Data Mining

MS2b: Stochastic Models in Mathematical Genetics

MS5a: Probability and Statistics for Network Analysis

MS6b: Advanced Simulation Methods

Computer Science Half-Units

Reports on the following courses may be found in the Mathematics and Computer Science examiners' report.

Quantum Computer Science

Categories, Proofs and Processes

Automata, Logic and Games

F. Comments on performance of identifiable individuals

Removed from public version.

G. Names of members of the Board of Examiners

- **Examiners:**
  Prof. J. Carr (External)
  Prof. D.R. Heath-Brown

Prof. P. Maini
Prof. Z. Qian
Dr D. Stirzaker (Chair)
Prof. A. Thomason (External)
Prof. J. Wilson

- **Assessors for Papers C1.1–C12.2**

Dr D. Belyaev
Dr G. Berczi
Dr Y. Capdeboscq
Prof. G. Chen
Dr de la Ossa
Prof. A. Ekert
Dr R. Erban
Prof. A. Fowler
Dr E. Gaffney
Prof. A. Goriely
Prof. B Hambly
Prof. R. Hauser
Prof. A. Henke
Prof. N Hitchin
Dr P. Howell
Prof. M. Kim
Dr Y. Kremnitzer
Prof. J. Kristensen
Dr A. Lipstein
Prof. P. Maini
Dr. L. Mason
Prof. C. McDiarmid
Dr K. McGerty
Dr N. Nikolov
Dr J. Oliver
Dr P. Papazoglou
Dr A. Paseau
Dr M. Porter
Dr A. Ritter
Prof. D. Segal
Prof. G. Seregin
Dr I. Sobey
Dr R. Suabedissen
Prof. E. Süli
Prof. U. Tillmmann
Dr D. Vella
Dr A. Wathen
Dr P. White
Prof. B. Zilber

- **Assessors for Dissertations**
  Prof. A. Ekert
  Prof. J. Ball
  Dr D. Belyaev
  Prof. H. Byrne
  Prof. P. Candelas
  Prof. J. Chapman
  Prof. B. Coecke
  Dr S. Cohen
  Dr D. Conlon
  Dr P. Dellar
  Dr C. Douglas
  Dr R. Erban
  Dr C. Farmer
  Dr E. Gaffney
  Dr K. Gillow
  Prof. A. Goriely
  Dr G. Gyurko
  Dr C. Hall
  Prof. B. Hambley
  Dr K. Hannabus
  Prof. R. Haydon
  Prof. A. Henke
  Prof. R. Heath-Brown
  Prof. N. Hitchin
  Dr C. Huenen
  Dr D. Joyce
  Dr R. Knight
  Dr Y. Kremnitzer
  Prof. L. Mason
  Prof. A. McLean
  Dr P. Neumann
  Dr N. Nikolov
  Prof. L. Ong
  Dr A. Papachristodoulou
  Dr P. Papazoglou
  Dr J. Pila
  Prof. C. Please
  Dr M. Porter
  Dr P. Read
  Dr C. Reisinger
  Dr T. Sanders
  Prof. D. Segal
  Prof. J. Tanner
  Prof. U. Tillmann
  Dr S. Waters
  Dr J. Whiteley
  Dr T. Woolley

Dr K. Yates
Pror. B. Zilber