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

August 30, 2012

Part I

A. STATISTICS

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

  See Table 1, page 1.

  When drawing comparison with historic data it should be noted that from 2009 classification for Part C was based on Part C alone.

- **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 %				
	2012	(2011)	(2010)	(2009)	(2008)	2012	(2011)	(2010)	(2009)	(2008)
I	45	(47)	(49)	(48)	(44)	45.45	(46.53)	(46.23)	(50.53)	(46.3)
II.1	36	(37)	(37)	(30)	(45)	36.36	(36.63)	(34.91)	(31.58)	(47.4)
II.2	15	(14)	(15)	(13)	(6)	15.15	(13.86)	(14.15)	(13.68)	(6.3)
III	3	(1)	(5)	(3)	(0)	3.03	(0.99)	(4.72)	(3.16)	(0)
F	0	(2)	(0)	(1)	(0)	0	(1.98)	(0)	(1.05)	(0)
Total	99	(101)	(106)	(95)	(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 7th February 2012 and the second notice on the 30th April 2012.

These can be found at https://www.maths.ox.ac.uk/notices/undergrad/part-c, and contain details of the examinations and assessments. All notices and 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 thank in particular 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, Vicky Archibald 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 James Vickers and Professor Andrew Thomason for their prompt and careful reading of the draft papers and insightful comments throughout the year.

Finally we thank the Physics Department for the prompt return of scripts for C7.4 (ahead of the deadlines Physics works to).

Timetable

The examinations began on Monday 28th May and finished on Monday 11th June.

Medical certificates and other special circumstances

The examiners were presented with medical notes for five candidates. There were minor misprints in four papers which did not require any changes to the marking scheme. There were errors in two papers which did require a change to the marking scheme for the paper.

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 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 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 5 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 $\rightarrow$ 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.

In the Corners Table, Table 2 on page 5 the following key is used :

- † denotes the use of no corners or corners have been inserted by hand;
- ‡ denotes the removal of one corner.

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	(14, 37)	(24.1, 57)	(35, 72)		8	1	2
C1.1b	(12.18, 37)	(26.5, 57)	(39, 72)		5	1	0
C1.2a ‡	(15.21, 37)	(36, 72)			3	4	3
C1.2b	(12.73, 37)	(24, 59)	(34, 72)		6	3	3
C2.1a‡	(19, 49)	(34, 72)			9	1	1
C2.1b †							1
C2.2a‡	(10.43, 37)	(30, 72)			2	0	0
C2.2b‡	(13.51, 37)	(32.4, 72)			7	1	0
C3.1a‡	(15.02, 37)	(36, 74)			10	2	0
C3.1b ‡	(12, 34)	(27.6, 72)			5	2	0
C3.2b	(12.22, 37)	(26.6, 57)	(38.6, 72)		8	2	0
C4.1a ‡	(13, 40)	(29.6, 72)			10	3	1
C4.1b‡	(14, 37)	(34.2, 72)			8	1	1
C5.1a‡	(13.23, 37)	(38.5, 72)			3	3	0
C5.1b‡	(15.44, 37)	(37, 72)			2	1	0
C5.2b‡	(14.79, 37)	(37, 72)			1	2	0
C6.1a	(14.34, 37)	(30, 60)	(37, 72)		2	4	4
C6.1b‡	(16, 37)	(36, 72)			3	1	2
C6.2a	(9, 37)	(16, 57)	(23, 72)		1	3	2
C6.3a	(12, 37)	(20.5, 57)	(42, 72)		13	19	9
C6.3b	(12, 37)	(25, 57)	(40, 72)		10	11	5
C6.4a	(12, 37)	(24, 57)	(38, 72)		9	12	4
C7.1b	(11.21, 37)	(24.4, 57)	(40, 72)		6	7	1
C7.2a	(13.37, 37)	(29.1, 57)	(39, 72)		6	1	0
C8.1a	(12, 37)	(17.2, 57)	(26.2, 72)		10	13	4
C8.1b	(13, 37)	(20, 57)	(41, 72)		12	21	9
C9.1a	(13.6, 37)	(29.6, 57)	(41.6, 72)		10	9	4
C9.1b	(12.41, 37)	(27, 57)	(42, 72)		9	5	1
C10.1a	(9.97, 37)	(24, 57)	(38.2, 72)		3	3	1
C10.1b ‡	(10.2, 37)	(23, 57)			1	2	1
C11.1a	(14, 37)	(20.8, 57)	(41.8, 72)		19	30	13
C11.1b	(14, 37)	(26.9, 57)	(37.4, 72)		11	15	7
C12.1a	(13, 33)	(26.5, 57)	(40, 72)		3	9	7
C12.1b	(12.18, 37)	(24, 56)	(32, 72)		2	5	3
C12.2b	(15, 37)	(21.9, 57)	(44, 70)		7	15	7
C12.3b	(10.94, 37)	(23.8, 57)	(40, 72)		2	6	3
MS1a	(14.3, 37)	(23.7, 57)	(40.2, 72)		7	9	7
MS2b	(15.44, 37)	(33.6, 57)	(43, 72)		5	11	7

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

Table 3: Percentile table for overall USMs

Av USM	Rank	Candidates with this USM or above	%
91	1	2	2.02
90	3	3	3.03
88	4	4	4.04
87	5	6	6.06
86	7	7	7.07
85	8	8	8.08
84	9	9	9.09
83	10	13	13.13
82	14	15	15.15
81	16	16	16.16
80	17	20	20.2
79	21	22	22.22
78	23	25	25.25
77	26	26	26.26
76	27	30	30.3
75	31	33	33.33
74	34	37	37.37
73	38	38	38.38
72	39	39	39.39
71	40	41	41.41
70	42	45	45.45
69	46	50	50.51
68	51	54	54.55
67	55	55	55.56
66	56	60	60.61
65	61	64	64.65
64	65	69	69.7
63	70	75	75.76
62	76	77	77.78
61	78	80	80.81
60	81	81	81.82
59	82	82	82.83
58	83	84	84.85
57	85	88	88.89
56	89	92	92.93
55	93	94	94.95
53	95	95	95.96
51	96	96	96.97
46	97	97	97.98
44	98	98	98.99
41	99	99	100

Table 4: Breakdown of results by gender

Class	Total		Male		Female	
	Number	%	Number	%	Number	%
I	45	45.45	38	50	7	30.43
II.1	36	36.36	25	32.89	11	47.83
II.2	15	15.15	10	13.16	5	21.74
III	3	3.03	3	3.95	0	0
F	0	0	0	0	0	0
Total	99	100	76	100	23	100

B. Breakdown of the results by gender

Table 4, page 7 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	11	32.45	10.05	69.09	17.06
C1.1b	6	39.17	8.86	77.5	17.03
C1.2a	10	33.1	6.47	67.4	10.99
C1.2b	12	33.92	6.26	72.92	9.74
C2.1a	11	33.91	10.66	72.64	17.58
C2.1b[1]	1				
C2.2a[1]	2				
C2.2b	7	36.29	4.86	78.14	7.76
C3.1a	12	40.25	5.01	82	9.33
C3.1b	7	29.29	13.61	68.57	24.27
C3.2b	10	40	6.65	77.8	12.71
C4.1a	14	30.14	8.52	70.93	14.47
C4.1b	10	38.8	11.33	79.9	20.9
C5.1a	6	42	6.81	81.83	15.07
C5.1b[1]	3				
C5.2b[1]	3				
C6.1a	10	33.5	5.34	66.6	9.4
C6.1b	6	30.5	11.67	63.17	21.44
C6.2a	6	20.83	7.08	64.67	11.5
C6.3a	41	32.2	10.35	65.05	13.52
C6.3b	26	34.88	9.04	68.12	12.89
C6.4a	25	31.6	10.12	66.04	15.1

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

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
C7.1b	14	37.07	6.96	71.86	10.91
C7.2a	7	37.29	5.5	71	10.89
C8.1a	27	23.11	5.79	65.33	11.38
C8.1b	42	29.88	9.23	63.19	10.82
C9.1a	23	38.3	6.87	71	12.83
C9.1b	15	39.6	6.87	73.73	11.83
C10.1a	6	31.67	11.38	67	17.83
C10.1b[1]	4				
C11.1a	46	33.89	9.4	67.65	13.58
C11.1b	22	35	6.16	69.82	10.91
C12.1a	17	33.06	88.8	65.29	14.29
C12.1b	10	28.7	3.02	65.3	5.85
C12.2b	29	36.03	10.93	67.14	15.54
C12.3b	11	33.55	6.73	67.55	9.11
C7.4[1]	2				
MS1a[1]	5				
MS1b	7	-	-	63.43	4.39
MS2a[1]	5				
MS2b	10	40	4.57	68.8	10.45
CCS1[1]	3				
CCS3[1]	4				
CCS4[1]	1				
Half Unit CD[1] Dissertation	1				
CD Dissertation	20	-	-	76.05	7.98
OD Dissertation[1]	1				

The tables that follow give the question statistics for each paper for Mathematics candidates.

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

C2.1b Representation Theory of Symmetric Groups

C2.2a Building Infinite Groups

C5.1b Fixed Point Methods for Nonlinear PDEs

C5.2b Calculus of Variations

C10.1b Brownian Motion in Complex Analysis

MS1a Graphical Models and Inference

Paper C1.1a: Model Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.13	15.13	6.62	8	0
Q2	18.4	18.4	4.86	10	0
Q3	11.4	13	5.03	4	1

Paper C1.1b: Gödel's Incompleteness Theorems

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	20.83	20.83	4.26	6	0
Q2	18.33	18.33	5.16	6	0
Q3	-	-	-	-	-

Paper C1.2a: Analytic Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18	18	2.83	8	0
Q2	13	14.33	4.32	3	1
Q3	16	16	3.97	9	0

Paper C1.2b: Axiomatic Set Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16	16	5.35	7	0
Q2	14.36	16.11	6.04	9	2
Q3	18.75	18.75	2.60	8	0

Paper C2.1a: Lie Algebras

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.54	17.54	6.77	11	0
Q2	15.43	15.43	3.99	7	0
Q3	16.6	18	5.77	4	1

Paper C2.2b: Finite Group Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.4	16.4	4.22	5	0
Q2	20.43	20.43	1.99	7	0
Q3	14.5	14.5	2.12	2	0

Paper C3.1a: Algebraic Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	21.45	21.45	3.80	11	0
Q2	14.67	19	7.61	4	2
Q3	19	19	2.87	9	0

Paper C3.1b: Differentiable Manifolds

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13	13	5.44	6	0
Q2	14	14	7.39	4	0
Q3	17.75	17.75	9.84	4	0

Paper C3.2b: Geometric Group Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	21	21	3.2	10	0
Q2	17	17	2.65	3	0
Q3	19.86	19.86	4.3	7	0

Paper C4.1a: Functional Analysis

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12.64	12.64	4.39	11	0
Q2	17.6	17.6	5.08	10	0
Q3	15.29	15.29	4.57	7	0

Paper C4.1b: Banach and C* Algebras

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.89	18.89	6.09	9	0
Q2	18.33	18.33	7.28	6	0
Q3	18.67	21.6	7.94	5	1

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

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	21.83	21.83	5.19	6	0
Q2	18.67	18.67	5.86	3	0
Q3	21.67	21.67	3.21	3	0

Paper C6.1a: Solid Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19	19	2.67	10	0
Q2	14.78	14.78	4.29	9	0
Q3	12	12	-	1	0

Paper C6.1b: Elasticity and Plasticity

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	9.67	12	5.03	2	1
Q2	14.17	14.17	6.11	6	0
Q3	18.5	18.5	6.45	4	0

Paper C6.2a: Statistical Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12.83	13.8	5.95	5	1
Q2	7.67	7.67	1.86	6	0
Q3	7	10	3	1	2

Paper C6.3a: Perturbation Methods

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	11.29	11.87	7.88	15	2
Q2	16.15	16.66	5.88	32	1
Q3	17.4	17.4	6.50	35	0

Paper C6.3b: Applied Complex Variables

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.95	17.1	6.28	20	2
Q2	16.55	16.55	4.62	20	0
Q3	18.23	19.5	6.39	12	1

Paper C6.4a: Topics in Fluid Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12.58	13.45	4.34	11	1
Q2	14.62	14.62	6.1	21	0
Q3	17.79	18.61	6.43	18	1

Paper C7.1b: Quantum Theory and Quantum Computers

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.77	18.77	4.87	13	0
Q2	19.25	19.25	3.14	12	0
Q3	13	14.67	4.24	3	1

Paper C7.2a: General Relativity I

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19	19	2.53	6	0
Q2	14.5	14.5	2.12	2	0
Q3	19.67	19.67	3.83	6	0

Paper C8.1a: Mathematics and the Environment

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	8	8.54	3.97	13	3
Q2	14.04	14.04	4.30	26	0
Q3	9.31	9.87	2.8	15	1

Paper C8.1b: Mathematical Physiology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.41	15.41	3.48	41	0
Q2	12.62	14.22	8.32	23	3
Q3	14.8	14.8	6.53	20	0

Paper C9.1a: Analytic Number Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.81	18.81	3.91	21	0
Q2	18.33	18.33	3.22	15	0
Q3	21.1	21.1	4.25	10	0

Paper C9.1b: Elliptic Curves

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16	16.5	7.21	4	1
Q2	18.54	18.54	3.13	13	0
Q3	22.08	22.08	2.81	13	0

Paper C10.1a: Stochastic Differential Equations

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15	15	5.43	5	0
Q2	15.17	15.17	6.18	6	0
Q3	24	24	-	1	0

Paper C11.1a: Graph Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.44	18.44	5.06	45	0
Q2	12.93	14.71	5.87	21	8
Q3	15.67	16.15	5.95	26	1

Paper C11.1b: Probabilistic Combinatorics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.4	15.4	2.61	15	0
Q2	20	20	2.31	7	0
Q3	18.14	18.14	3.64	22	0

Paper C12.1a: Numerical Linear Algebra

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.47	19.13	4.84	16	1
Q2	5.88	7.33	3.98	6	2
Q3	16.31	17.67	6.5	12	1

Paper C12.1b: Continuous Optimization

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	10.4	16	6.58	2	3
Q2	12.88	12.88	2.03	8	0
Q3	15.2	15.2	1.23	10	0

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

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.54	16.36	6.87	25	1
Q2	18.47	19.63	7.28	16	1
Q3	18.94	18.94	5.96	17	0

Paper C12.3b: Approximation Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	11	-	5.29	0	3
Q2	18.09	18.09	4.99	11	0
Q3	15.45	15.45	3.80	11	0

Paper MS2b: Stochastic Models in Mathematical Genetics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.44	18.63	5	8	1
Q2	21.5	21.5	1.93	8	0
Q3	19.75	19.75	0.96	4	0

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

The Part C examiners would like to support the recommendation being put forward by other examination boards that the point at which the line of the scaling graph intersects the y-axis be changed to (0, 10).

E. Comments on sections and on individual questions

The following comments were submitted by the assessors.

C1.1a: Model Theory

Question 1 13 out of the 23 candidates took this question with an average of 15 marks. Most parts were bookwork or from exercises. Part (d)(iii) " $\Leftarrow''$ was only solved by 2 students (using Ryll-Narelzewski); many argued that if there are elementary embeddings from $\mathcal{A}$ to $\mathcal{B}$ and from $\mathcal{B}$ to $\mathcal{A}$ then $\mathcal{A} \cong \mathcal{B}$ which, in general, is false.

Question 2 20 students took this question with an average of 16.9 marks. The bookwork in (a) and (b) was typically well reproduced. In (c)(i) it was often overlooked that models should be infinite. Only 3 candidates managed (c)(iii) which requires a thorough understanding (the key idea coming from a correct solution of (c)(ii)).

Question 3 14 candidates took Question 3 with a weak average of 12.1 marks, probably because people ran out of time. It is not a difficult question if one remembered the proof of the Omitting Types Theorem. Again, only 3 candidates got (c)(iii) right, which was novel, but quite elementary.

C1.1b: Gödel's Incompleteness Theorems

16 candidates took the exam in this subject, 6 Maths and 10 Maths and Phil. The standard was generally high, with six answers that attained full marks. The average mark was 20,

both for the Maths candidates and the Maths and Phil candidates, and no candidate did very badly.

Question 1 Called for versions of the proof of both parts of the First Incompleteness Theorem (first half in the first part of part (d), second half in part (b)), and a lemma from the proof of the Second Incompleteness Theorem in part (c). The second part of part (d) used a variant of the fact, proved in the course, that a system extended by the negation of its Gödel sentence proves the negation of the Gödel sentence for the extended system, and the fact needed in part (c), that the a system with a Gödel sentence proves the equivalence of its Gödel sentence with the consistency statement for that theory. This question had a somewhat higher average mark than the other two, perhaps reflecting the fact that it covered the most central results of the course.

Question 2 Focused on the Separation Lemma and Rosser's Theorem. Parts (a) and (b) were bookwork and generally well done. Part (c) was different from, though similar to further material on Rosser's Theorem covered in the course, which built on parts (a) and (b). Part (d) was new, and required clear thinking to construct an argument not seen before. The most common source of difficulty for those candidate who struggled with parts (c) and (d) was lack of facility with the properties of enumeration of a set by a formula in a system, while others gave some very nice answers, including one particularly elegant solution to part (d).

Question 3 Covered Löb's Theorem and the system of provability logic GL based on Löb's Theorem. This question was answered by 7 of the Maths and Phil candidates and by none of the Maths candidates. Parts (a), (b), and the first part of (c) were bookwork. Non-bookwork was the second part of (c), which required candidates to find two simple fixed points and to prove the fixed point equivalences for them.

C1.2a: Analytic Topology

Question 1 A popular question. The technically demanding proof of Urysohn's Lemma was carried out quite well, leading to overall good marks (typically 2.i and better) for this question. The proof that separated F_σ sets in a normal space can be separated by open sets, was difficult. Many candidates constructed open sets which were not, in fact, disjoint. Some realized this, but didn't rectify this properly. Some candidates attempted to use functional normality, but missed that one needed to construct two functions and combine them. Only very few candidates gave an example in part (c), although any non-hereditarily normal space would do (and at least one of them was given in lectures).

Question 2 The least popular question, but the majority who attempted it gained high (first class) marks. The first two parts were done well, in part (c) some failed to apply what they had proven in part (a) and stated in (b); in part (d) the main difficulty was choosing the right subspace to which to apply (c).

Question 3 Very popular question with generally high marks (mostly 2.i and better). The modular nature of the question worked to the advantage of the students.

Although the mathematics required was in some sense elementary, the main difficulty seemed to be obtaining the correct filters or ultrafilters to give rise to a contradiction. Unravelling the quantifications (e.g. if all ultrafilters have some property then ...) seemed to be hard. No-one gave an example of a convergence relation for which the 'natural' closure operation given by $c(A)$ is not idempotent, although problem sheet 1 contained a question to that end.

C1.2b: Axiomatic Set Theory

There were 22 candidates who took this paper.

Question 1 (attempts 17, mean 15.76, median 14)

This question concerned the Cumulative Hierarchy. The bookwork in parts (a) and (b), which established some fundamental properties of V, was generally done very well, and mistakes that were made were unnecessary and surprising; for example, several candidates completely omitted any indication as to how the induction proceeds at limit cases. The most difficult part of the question was to adapt the proof given in lectures that V satisfies the Replacement Scheme to prove that every instance of AR* is provable in ZF, and it seemed to separate candidates well. Those who answered part (d) generally recognised how to make use of the set b guaranteed to exist by part (c), but perhaps let themselves down with the formal expression of the proof.

Question 2 (attempts 21, mean 14.38, median 15)

This question concerned absoluteness. The bookwork in part (a) was generally done well, with the best candidates making themselves known by using the correct manipulations on, and by making the distinction between, parameters and variables of LST formula. Part (b) required some sophistication in bringing together definitions and results from different parts of the course, and it was hoped that it would perhaps be done a little better. There are two striking ways in which candidates could have improved their solutions here: by making explicit use of ZF theorems such as "every well-ordering is order isomorphic to an ordinal" and "a transitive set totally-ordered by $\in$ is also well-ordered by $\in$"; by using reasonable abbreviations to give clear and concise expressions of the relevant LST formula. Part (c) was well done, and often answered in more generality than actually required.

There were some typos in the question which were queried and rectified during the exam.

Question 3 (attempts 9, mean 14.33, median 15)

This question concerned cardinal arithmetic, and was attempted by noticeably fewer candidates. Traditionally, this is the part of the course that students find to be the hardest, and so this is not surprising. The bookwork in part (a) was done well, but candidates found the arithmetic in the remainder of question, notably part (b), to be difficult. Not many candidates attempted part (c), with only one candidate giving a confident answer to it, explaining why GCH has failed and why the least α such that $V_\alpha \notin L$ is a successor ordinal.

There was a query about the definition of singular during the exam, and it was allowed to be announced that a cardinal which is not regular is singular.

C2.1a: Lie Algebras

Question 1 was the most popular question with all candidates attempting it. Most wrote solid answers to the first two parts, which were bookwork. A key point in Lie's Lemma, that you can find a subspace on which the Lie bracket is a commutator, was not made clear in many solutions however. A number of candidates also figured out good solutions to the final two parts, but a number failed to notice in part (c) that they had to produce a $\mathfrak{g}-$subrepresentation, not just a $\mathrm{rad}(\mathfrak{g})$-subrepresentation of V.

Question 2 was the next most popular. The inductive step in the bookwork of part (a) was often fudged. Many students had the right strategy in the second part, but strangely the last part confounded almost all students, though many were considering examples very close to the correct one.

Question 3 was attempted by only about a third of the students, but about half those who attempted it produced good solutions - the main issue being to find a way of classifying rank two root systems cleanly. There was a minor typographical error in part (a) ($\cos^2(\theta)$ could also be equal to 1) but this part was uniformly well answered, so no confusion seems to have occurred.

C2.1b: Representation Theory of Symmetric Groups

Question 1 No one got (d) last part. "Maximal" was treated too cavalierly.

Question 2 After establishing the correspondence of differential forms, nobody thought to discuss exactness or otherwise in part (d).

Question 3 Bookwork - they all knew more or less what to do.

C2.2a Building Infinite Groups

C2.2b: Finite Group Theory

Question 1 was answered, on the whole fairly successfully, by half a dozen of the students. Most marks were picked up on the early parts of the question, with nobody seeing the trick needed to solve the tough (b)(iii), although that was only worth a couple of marks.

Question 2, anticipated to be the most popular, was slightly more routine, and attempted by every candidate. Marks scored were high on this question, perhaps due to the fact that more bookwork was involved. Although one person spotted the trick needed to solve the last part of the question, they didn't see to apply it again to finish the question, and so again unfortunately nobody got full marks.

Question 3 was expected to be less popular and it indeed was, with three answers; on the whole they were satisfactory, although again the tough (d)(ii), intended to be a far stretch, attracted no complete solutions, although some valiant attempts were submitted.

C3.1a: Algebraic Topology

Question 1 This question tested the basics of simplicial homology theory. It was quite long and some candidates got somewhat lost in the computations. The computation of the homology of $Y_\bullet$ caused most trouble. In the last part of the section not all candidates explained that $Y_\bullet$ attached a cone on $A_\bullet$, and therefore had the same homotopy type as $X_\bullet/A_\bullet$.

This question was attempted by all but one candidate.

Question 2 The Mayer-Vietoris sequence for mapping tori had not been covered in lectures but of course is a standard application that students might have seen in the text book or as part of previous exams. Most candidates who attempted this question found the right covering for the application of the Mayer-Vietoris sequence but had trouble understanding the induced maps. This should not have hindered candidates to go on to the applications, and those who did, did quite well.

This question attracted 4 answers and 2 further attempts.

Question 3 This question covered the latter part of the course and required a good understanding of the main theorems, the Universal Coefficient Theorem and the Poincare Duality Theorem. The applications were not easy with part (f) being the hardest. It was pleasing to see that the majority of candidates did quite well here and even the harder parts were solved by some candidates.

There were 10 attempts for this question.

C3.1b: Differentiable Manifolds

C3.2b Geometric Group Theory

Question 1 All candidates attempted Q.1. Most found difficult the last question of 1(a). (No one thought of calculating the abelianization!). 1b was done by most but few had some difficulty explaining why one can list homomorphisms to Sn.

Question 2 Few (3) candidates attempted this - perhaps because it relates to the most technical part of the course. In 2(b) some showed that the elements commute but did not justify properly the isomorphism to $\mathbb{Z} \times \mathbb{Z}$ The first part of 1c was not treated in sufficient detail.

Question 3 Most candidates did not think to use Milnor-Svarc for 3(a). Some did not manage to justify the claim that $A * B$ has exponential growth. Most had the right idea but few managed to justify in detail why G is isomorphic to $\mathbb{Z}$. 3(b) was treated well.

C4.1a: Functional Analysis

C4.1b: Banach and C^*-Algebras

General Comments

The number of candidates sitting this paper was double that of 2011. As usual, the quality was very high with seven candidates in the high first-class region, and only one who struggled. There were eight attempts at the first question, six at the second, and six at the third.

Individual questions

Question 1 There were six solutions to this question at the α level, but only one or two of the candidates were able to give a full description of the Gelfand representation of the commutative unital Banach algebra $l^1(G)$ where G is a cyclic group of order n.

Question 2 Four out of the six solutions were of α standard, the functional calculus for normal elements of a unital C*-algebra being well-understood. All these candidates spotted that the hint to the last part of the question would have been even more helpful without the $\frac{1}{2}$.

Question 3 This question was set on the final part of the course and it was gratifying to see that it produced three questions at the α level and two at the β^{++} level.

C5.1a: Methods of Functional Analysis for PDEs

Question 1 was attacked by all the candidates. The theoretical part was not very difficult for them. Most of the candidates successfully solved part (b) as well.

Question 2 was attempted by a half of the candidates. Friedrich's inequality was proved by everyone while, surprisingly, the theorem on the extension of functions with weak derivatives was perfectly stated in very few cases. Multiplicative inequality, part (b), was proved by most of the candidates.

Question 3 seems to be the most challenging for candidates, especially, its part (b). There were some difficulties in calculations of divergence of a vector field to show the coercivity of the corresponding bilinear form. In the theoretical part, minor difficulties were caused by proving the compactness of an operator generated by weaker terms.

C5.1b: Fixed Point Methods for Nonlinear PDEs

All students chose the first two questions, and answered them very well.

Question 1 The main difficulty in question 1 seemed to be obtaining a Lipschitz constant ($\frac{1}{2}$ was not too difficult to obtain, but was not proved by the candidates).

Question 2 Problem two was also globally well done. Several solutions were proposed to the last question, as expected.

C5.2b: Calculus of Variations

Question 1 This was very popular and attempted by all the candidates. It was clear that some important concepts such as weak (strong) local minimisers and the second variation, the derivation of the weak Euler-Lagrange equation, and the role of the second variation for a weak local minimiser, had been well learnt. Part (d)(ii)-(iii) were found difficult. Only one candidate got the correct idea to attempt (ii). None of the candidates worked out (iii) completely.

Question 2 This question was attempted by only one candidate who did quite well. The candidate got the right routine to attempt all of the parts. However, there were still some errors in attempting Part (c) (i)-(ii).

Question 3 Part (a) was generally done well, though one candidate did not attempt (i) and another failed to give a complete proof for (ii). Part (b) (ii) was attempted well. Part (b) (iii) was not attempted as well as I had expected. These questions gave a good opportunity for the stronger candidates to show their better understanding for the Cauchy inequality, the dominated convergence theorem, the weak lower semicontinuity. Surprisingly, only one candidate did reasonably well.

C6.1a: Solid Mechanics

Question 1 All students attempted this question, scoring reasonably well, with more than half of the class scoring above 20/25. Part (a) was all bookwork; however, many students confused the Cauchy-Green strain tensors with the stretch tensors resulting in some marks being lost. In part (b) many students failed to correctly express the difference between the Cauchy and the Piola-Kirchhoff stress vectors, claiming that the latter expresses forces in the reference configuration; almost all got full marks for the remainder of part (b). In part (c), some students encountered difficulties differentiating the not-so-trivial stored energy function given to them. Although similar differentiations had been done in the course, this seemed to be the hardest part of Q1. Most students were able to calculate the resultant surface forces, while some seemed to confuse the 'resultant surface force' with the 'surface force per unit area'. Few students did not see that they had to consider $\gamma \to 0$ to deform the body to zero volume.

Question 2 All but one student attempted this question; however, the standards of answers were not as good as Q1, with only one scoring above 20/25. Part (a) was straightforward though couple of students seemed confused with the definitions of isotropy and frame-indifference. In part (b), although part of the lecture notes, half of the students were either not able to calculate the Piola-Kirchhoff stress tensor or claimed that the gradient of the radial deformation is diagonal itself, rather than diagonalizing and using the hint. As for calculating the radial component of the Cauchy stress, this required some linear algebra and only one student did it correctly. Here, the students who had claimed that the Piola-Kirchhoff stress is diagonal, found a diagonal Cauchy stress and simply considered one of its diagonal entries which gave the correct result (perhaps this led them to claim that T_R was diagonal in the first place). In part (c) (i), no one was able to deduce the required inequality. Only couple of students reached far enough to understand that the given deformation cannot be linear and used the hint to claim that due to continuity either $r' - r/R < 0$ or $r' - r/R > 0$ for all R; still, they did not see the short, but non-trivial, trick to get the result. To show that $\sigma(R)$ is strictly increasing they had to follow an exercise from an example sheet and most found that straightforward. Part (c) (ii) was more difficult and was hardly attempted by anyone.

Question 3 Students felt that the part of the course on phase transformations was the most difficult one and only one attempted Q3. Parts (a) and (b) were bookwork and a short exercise which was done in revision classes; nevertheless, answers were incomplete. Part (c), although similar calculations had been seen before, was certainly more difficult and required a good handling of linear algebra which seems to be missing from 4th year undergraduates. As a result, the standard of answers was lower than expected.

Overall, this course requires a familiarization with calculus in multiple dimensions and linear algebra which seemed to be the underlying difficulty encountered by most students.

C6.1b: Elasticity and Plasticity

The questions, compared to previous years, were found to be relatively easy by the assessor (and myself). In particular, the material found in the questions was mostly covered during the lectures (with very little new material and detailed hints). Basic lecture material would have guaranteed a IIi or IIii. Despite that, basic understanding was lacking: as demonstrated by some trivial mistakes between stresses and force (Question 1), in some simple solutions of linear differential equations (Question 2), and in some elementary derivation of linear elasticity (Question 3).

C6.2a: Statistical Mechanics

Question 1 All 6 students tried this problem. One student did an excellent job, and everybody else was confused to some extent. Parts (e) and (f) were meant to be tricky, and I was very pleased to see a 24/25 on this question given that. I was surprised that when asked to explicitly give $\Omega(E)$ [i.e., as a function of E] that several students gave answers not in terms of E. I didn't expect the difficulties I saw with part (d). Overall, I think this problem was the most "successful" one in terms of design.

Question 2 All 6 students tried this problem. I thought part (a) wouldn't pose a problem because it was right out of the lectures, but there was some confusion [so 3/6 was a common score by getting certain aspects right but not the whole thing] and, surprisingly, some students seemed to not realize that each part had both a 'define' and an 'indicate'—i.e., that 2 different but short things were expected for each situation. There were a couple of reasonable attempts at part (b), but nobody got it completely. Part (c) caused problems in expected places (e.g. entropy of system versus overall entropy), but there was one and arguably two glitches in design with unexpected derailment: [1] Students who got c(iii) wrong seemed to be derailed for c(iv); [2] some students didn't seem to realize that a setup and calculation was expected, so I wished I had phrased it as "By setting up (...), show that." to be crystal clear that it was a calculation that was expected—in contrast to c(i), c(ii), and c(iii). There were no reasonable attempts at c(iv), so I think I asked that question the wrong way.

Question 3 Only 3 students attempted this problem. Part (a) was out of the notes, but it was mostly skipped. Nobody got (b) completely right, and in fact students missed the fact that they needed to write down a Hamiltonian to specify the Potts model. There were some reasonable attempts at part (c). There was one good attempt at part (d). Only one student attempted (e). Part (f) was not attempted by any student. I think that Problem 3 was a fair problem, but perhaps the students (incorrectly) viewed it as harder than the others, so fewer attempted it? Perhaps this is because this covered material from the last part of term?

C6.3a: Perturbation Methods

Question 1 Bookwork part of (a) was not done well by some candidates. In (i) and (ii) few candidates checked the condition on $f(t)$ at infinity to make sure the lemma was applicable. Part (b) was rather tricky but some candidates answered it well.

Question 2 Overall, well done. However, it was surprising how few candidates got (a)(i) or (a)(iii) correct. Common mistakes on (a)(i) included not having the trajectories cross the x-nullcline vertically, and not explaining why the trajectory "falls off" the turning points on the nullcline. For (a)(iii) some candidates had the fast dynamics lasting almost as long as the slow dynamics.

Question 3 Well done in general. Some candidates missed the possibility of secular terms at order ϵ in part (b). Most missed that at order ϵ^2 the secular terms are composed of contributions of the T_1 derivative of x_1 as well as those from x_0.

C6.3b: Applied Complex Variables

Question 1 This question was attempted by all but three candidates. The bookwork in part (a) was well done, though a handful of candidates failed to locate correctly the inlet in the hodograph plane. The conformal mapping in part (b) and the derivation of the differential equation in part (c) was less well done, with numerous algebraic slips. The tail in part (c) was done poorly, the majority of candidates failing to write down the correct boundary conditions.

Question 2 This question was attempted by about 75% of the candidates. The derivation of the Plemelj formulae in part (a) was very well done, though a large number of candidates carelessly dropped marks for not justifying their use of the deformation theorem or the existence of the Cauchy principal value integral. In part (b) the majority of the candidates were able to use the Plemelj formulae to derive correctly the density F and the solution to the singular integral equation. A significant minority were able to derive correctly the integral identity in part (c), which required an understanding of the Plemelj formulae and of multi-valued functions. There were no good attempts at part (d), which was too hard.

Question 3 This question was attempted by about 45% of the candidates. The bookwork on the Wiener-Hopf method in part (a) was very well done, though a large number of candidates carelessly dropped marks in parts (a)(ii) and (a)(iii) for failing to justify fully their use of part (a)(i). In part (b)(i) the strong candidates quickly and efficiently derived the given relation, though a significant minority failed to define the regions in which the various Fourier transforms exist. Part (b)(ii) was well done on the whole, being very similar to a problem sheet question. Part (b)(iii) was answered correctly by more than half of the candidates.

C6.4a: Topics in Fluid Mechanics

Question 1 Students found this question more challenging than anticipated. The proof of the generalized Archimedes' principle in part (a) was generally very poorly done with only a couple of complete attempts. In part (b) many students were apparently not familiar, or were careless, with the expression for $\nabla\cdot\mathbf{n}$ in cylindrical coordinates despite being able to use it elsewhere (e.g. in Q2). No candidate was able to determine an expression for the weight of liquid displaced; common mistakes included using the $r \ll 1$ asymptotic expression for $K_0(r)$ as $r \to \infty$, integrating from 0 (rather than R) and not including the factor of r (from axisymmetry) in the integrand. Nevertheless, several candidates persevered to the end and were able to perform the matching required in 1 b(iv) successfully.

Question 2 This question received a mixture of responses. Most candidates were able to obtain the governing pde and perform some scaling analysis. However, the relevance of this scaling analysis to the requested similarity solution was not always appreciated and many candidates were unable to marshall the algebra required to find the similarity solution itself. There were only a few correct attempts at part (b). Those who used the correct change of frame generally did not then note that the problem then became precisely that considered in (a) (albeit with a modified value of g).

Question 3 This question was generally well done. Students were generally slightly careless with the scaling in the first part, often not realising that time had to be rescaled as well leading to solutions that were dimensionally incorrect. Part (b) was generally well done though a surprising number did not express the velocities in terms of $\partial \log p/\partial x$ etc. to simplify the algebra, as had been done in lectures. The attempts at part (c) were generally good, though some thought that the resulting generalized thermal windshear equation was at odds with what had been derived in (b).

C7.1b: Quantum Theory and Quantum Computers

Question 1 worked reasonably well, producing a good spread of marks for both the third and fourth year candidates. There were several perfect or near perfect solutions, and most people managed to get at least 10.

Question 2 was less successful, at least for the fourth year candidates (though it spread the third year candidates reasonably well). In part this was because almost everybody knew the bookwork, and nobody could do the last part, which had been intended to separate the first class from the rest. Two or three candidates realised what the question wanted them to do, but had forgotten the form of the angular momentum terms in the Hamiltonian, and so were unable to carry that out. (The very first draft of the question had given that information, but it was removed during the checking in case it confused candidates earlier in the question.)

Question 3 Twelve students tried the Quantum Computing question this year, more than in any other recent year. Nobody managed the whole question, but there were two reasonably good solutions, both from third year students, and it produced a wide spread of marks. It may be that the third year students fared better because they have had less time to forget their Linear Algebra, as that was where most of the problems arose, particularly in discussing the relationship between entanglement and the purity of the partial trace. One or two candidates seemed to think it reasonable to pull a linear operator outside an inner product and then put it back when they needed to reach agreement with the stated answer.

The proportion of really good scripts was much the same as that of first class solutions received to the class problem sheets. Fortunately there were only a couple of the really weak scripts on which I commented last year.

C7.2a: General Relativity I

Question 1 Six candidates attempted this question. Parts *a* - *c* of this question involved some bookwork and most students did well on these parts. In deriving the Riemann tensor in part *b*, some students incorrectly evaluated the covariant derivative of $\nabla_\mu X^\nu$. Also, some students did not make use of inertial coordinates in part *c*, which asked the candidates to derive various symmetries of the Riemann tensor. Some students had difficulty with part d, which was the most challenging part of the question since it required several manipulations which make use of Killing's equation and various symmetries of the Riemann tensor.

Question 2 Two candidates attempted this question. Common mistakes were not pointing out that the equivalence between gravity and acceleration only holds locally in spacetime when asked to define the "Strong Principle of Equivalence" in part a, and not recalling the covariant definition of acceleration, which was required in part c of the question. Part d of the question asked the students to compute the redshift of a photon in these coordinates. Candidates correctly performed the transformation to inertial coordinates in part e, but did not correctly identify the region of Minkowski space covered by the original coordinate system, although their answers were almost correct. Overall, this question demanded a good command of several concepts, so the students may have had a little bit of difficulty with this question.

Question 3 Six candidates attempted this question. Parts a - c of this question involved some bookwork and most students did well on these parts. In part c, the candidates were asked to compute the effective potential for a time-like geodesic of the Schwarzchild metric and explain the physical significance of this potential. Marks were lost for not explaining the physical significance of various terms in the potential. Most students had difficulty with part d of the question, which asked the candidates to sketch the effective potential, compute the radii of circular orbits, and compute the radius of the innermost stable circular orbit (ISCO). Only one student accurately sketched the effective potential. Three students recognized that the radii of circular orbits correspond to the extrema of the potential, but none of the students computed the radius of the ISCO. The computation of the ISCO was not explicitly seen before in the course.

C8.1a: Mathematics and the Environment

Question 1 and 3 Both questions were extremely poorly done, with respective top marks around 15. This despite the extremely simple manipulations involved. The reason may partly lie in pitching the questions outside the comfort zone (ice sheets not glaciers, radiative heat transfer not energy balance), and suggests an unwillingness of the student to study the material in the course text much beyond the lectured material. If this is so, it suggests a reversion to a more cramped and less excursive lecturing style; or it may simply be that the challenge to engage with real physical principles, even at fourth year level, is still daunting.

Question 2

Surprisingly the real difficulty was in changing variables in a p.d.e. i.e. from $a(x,t) \to a(j,z)$.

Other issue was that a lot of the students had difficultly in completing the linear stability analysis for the system of poles for water and sediment transport

C8.1b: Mathematical Physiology

Question 1 A popular question with a standard start that was tackled very well by the vast majority of students; only students who had clearly not prepared at all for the exam did poorly here. In the non-standard part of the question, most students did not appreciate that the lecture-note technique of demonstrating the gating variable w was zero in the wavefront was insufficient here due to the non-autonomy. Many students recovered nonetheless in the final part of the question though the boundary conditions for the transmembrane potential for the inner region were poorly explained in many cases.

Question 2 Overall the majority of the question was well done, though a few candidates did get bogged down in the derivations. In the later parts, a significant minority of candidates persevered into the final parts to derive a linear equation for h at leading order in δ. However, most at this final stage then considered perturbations of the form

$$h \approx \exp[\sigma t] \exp[iks]$$

and tried to explore whether $Re(\sigma)$ was positive or negative. While this was a standard technique in the lectures to consider stability, in this case it is invalid as it does not respect the boundary condition $h \to 0$ as $s \to \infty, -\infty$.

Question 3 Overall this was well done, with most students doing well in the early parts of the question but with most gradually fading as the question got harder nearer the end. There was a typo in the expression given for a "show that" in the penultimate parts but students reaching this far ignored or just noted this, carrying on with the final part of the question with no further implications.

C9.1a: Analytic Number Theory

There were 23 candidates. Almost all attempted Q1, with their second question evenly split between Q2 and Q3. The marks on the whole were high - the paper was slightly too easy. The only question which proved difficult was to show that $H(s)$, in Q1, was absolutely convergent for $Re(s) > 1/2$. Elsewhere mark losses were mainly due to imprecision.

C9.1b: Elliptic Curves

There were 17 candidates (including 2 M&P). Questions 2 & 3 were slightly more popular than Question 1, but all attracted some good attempts. Question 3 was a bit easy, but otherwise there was a good spread of marks.

C10.1a: Stochastic Differential Equations

The exam overall appeared to be well balanced with most students able to show their knowledge on the early parts of questions and the tails proving challenging.

Question 1 was popular with most students scoring well, though the tail proved tricky with only one successful attempt.

Question 2 had a substantial bookwork component which was well done. The later Ito calculus exercise and uniqueness proof were more mixed.

Question 3 was largely bookwork, only one candidate did the question and produced an almost perfect solution.

C10.1b: Brownian Motion in Complex Analysis

Question 1 The first part of the question (statement of the theorem and its straightforward application) was done well. The second part turned out to be more difficult, mostly in the part where one have to deal with conformal maps.

Question 2 Again, part (a) was done well by all students who attempted it. In the part (b) the standard mistakes are: ignoring dependence of the exit distribution of the starting point and ignoring the fact that the function f is defined only on the circle.

Question 3 Part (a) (the statement of Levy theorem) was a quite easy piece of bookwork. In part (b) there where many mistakes in operating with conformal maps. In the part (c) most of the students had the right idea but had problems with writing it down.

C11.1a: Graph Theory

Candidates: maths 46, maths/stats 17, math/phil 7, maths/cs 7, total 77. Q1 was attempted by all candidates, Q2 and Q3 each attracted about 50 attempts. (15 candidates submitted 3 questions.)

Question 1 Two parts (a) Ramsey number $R(Ks, T)$ - bookwork. Part (b) Hamilton circuit condition - mostly bookwork but with a rider which is easy in the cool light of day but caused some difficulties. Overall this was a little too easy for good students. There were about 13 near perfect solutions, but apart from that there was a fair spread of marks.

Question 2 Bipartite matchings and edge-colouring. Mostly well done, except for part (c) which was rarely well done and caused more trouble than anticipated. For (c) part (i) it was simplest to break into two (very similar) cases: either both ends of the path are in X or both are in Y - that done it is not hard. In (c) (ii) few noticed that you can get cycles (which are easy to handle). Typical marks on this question were lower than on the other questions (though math/phil students did very well).

Question 3 Two parts (a) Erdos-Stone theorem and the density $ex(n, H)/\binom{n}{2}$. Mostly well done bookwork, but hard unless you were on top of the proofs. Part (b) Exercise on regularity, rather easy for most, almost all did this part well. Overall a good spread of marks.

C11.1b Probabilistic Combinatorics

Overall the answers were fairly good, with several answers to individual questions going well beyond what was expected. The question on the most basic material (Q1) was deliberately slightly less straightforward than in some previous years, in an attempt to balance the paper.

Question 1 (a) is routine bookwork and was done well. Part (b) is a minor variant of a proof from lectures (the balanced case), with partial credit given for just giving the bookwork version. Only a few candidates took the latter option. This was generally reasonably well done. No candidate managed part (c), perhaps because it requires 'switching gears' (in a manner suggested in the hint). This was only a few marks.

Question 2 was attempted by the fewest candidates. All did well on the bookwork. Part

(c) confused some candidates, though with appropriate use of Theta notation it is possible to give a very short answer. Overall this question had the highest marks.

Question 3 was attempted by every single candidate. Disappointingly, many candidates (including a majority of the Maths & Stats ones!) could not correctly define independence for more than two events. About half the candidates found an example for the end of part (a) (one was in lectures, and another on the problem sheets). Part (b) was easy and generally well done. Part (c) follows a standard pattern and was mostly well done, though many candidates said joining the dependent events give a dependency digraph (despite part (a)).

C12.1a : Numerical Linear Algebra

Question 1 and question 3 were good tests of candidates' knowledge but question 2 unfortunately was reasonably tackled by only one candidate and otherwise attracted rather low marks.

C12.1b : Continuous Optimisation

The take-up of question 1 was lower than on the other two questions, although the level of achievement was similar as on other questions amongst those students who gave it a serious attempt. The earlier parts on all questions were better solved than the later parts, some of which were quite hard. There were no negative outliers in overall achievement, but there were also no candidates attaining top marks, which suggests that the exam was a bit too hard.

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

29 candidates took the paper.

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. 26 candidates attempted the question, 10 of whom produced high-quality answers. There were also 9 rather poor attempts: these candidates were unable to correctly state the weak formulation of the boundary-value problem, which then resulted in unsuccessful attempts at proving the coercivity of the associated bilinear form.

Question 2 This question was concerned with the analysis of the continuous piecewise linear approximation of a nonhomogeneous Robin boundary-value problem for the elliptic equation $-\Delta u + u = f$, restated as an energy minimization problem. There were 17 attempt at the question. Of these, 10 were of high quality. There were two weak and two very weak attempts.

Question 3 The question was concerned with the construction and stability analysis of the Crank–Nicolson finite element approximation of a second-order parabolic initial-boundary-value problem. There were 17 attempts at this question, 9 of which were very strong. There were also three rather weak attempts.

C12.3b Approximation of Functions

It was striking that whereas every student attempted Questions 2 and 3, only 3 attempted Question 1. In fact Question 1 was no harder than the others, but it asked the students to consider a particular example rather than general theory, and I am well familiar with the phenomenon that Oxford students are nervous of particular examples.

Statistic Half-Units

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

MS1a : Graphical Models and Inference

MS1b : Statistical Data Mining

MS2a: Bioinformatics and Computational Biology

MS2b: Stochastic Models in Mathematical Genetics

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.

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