

Examiners' Report: Final Honour School of Mathematics

Part C Trinity Term 2026

October 27, 2026

Part I

A. STATISTICS

- **Numbers and percentages in each class**

See Table 1, page .

- **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 dissertations and mini-projects 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 A1.

- **Numbers taking each paper.**

See Table 7 on page .

Table 1: Numbers in each class (post-2021 classification)

	Number						Percentages %					
*	2026	(2025)	(2024)	(2023)	(2022)	(2021)	2026	(2025)	(2024)	(2023)	(2022)	(2021)
Distinction	50	(57)	(71)	(61)	(46)	(60)	58.14	(60.64)	(66.36)	(64.89)	(58.23)	(60)
Merit	17	(21)	(26)	(21)	(19)	(20)	19.77	(22.34)	(24.3)	(22.34)	(24.05)	(20)
Pass	18	(13)	(10)	(12)	(14)	(18)	20.93	(13.83)	(9.35)	(12.77)	(17.72)	(18)
Fail	1	(3)	(0)	(0)	(0)	(2)	1.16	(3.19)	(0)	(0)	(0)	(20)
Total	86	(94)	(107)	(94)	(79)	(100)	100	(100)	(100)	(100)	(100)	(100)

Table 2: Numbers in each class (pre-2021 classification)

	Number					Percentages %				
	2020	(2019)	(2018)	(2017)	(2016)	2020	(2019)	(2018)	(2017)	(2016)
I	63	(58)	(53)	(48)	(44)	67.74	(57.43)	(56.99)	(57.14)	(50.57)
II.1	30	(40)	(26)	(23)	(31)	32.26	(39.6)	(27.96)	(27.38)	(35.63)
II.2	0	(2)	(13)	(12)	(9)	0	(1.98)	(13.98)	(14.29)	(10.34)
III	0	(1)	(1)	(1)	(3)	0	(0.99)	(1.08)	(1.19)	(3.45)
F	0	(0)	(0)	(0)	(0)	0	(0)	(0)	(0)	(0)
Total	93	(101)	(93)	(84)	(87)	100	(100)	(100)	(100)	(100)

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

The examiner's note that the following planned change to the Part C Mathematics examination conventions is currently under consideration:

- Students will be required to offer at least 4 units which are assessed by written invigilated examination. The current exam conventions require students to offer a minimum of 3 units assessed by written examination.

C. Notice of examination conventions for candidates

The first notice to candidates was issued on 18th February 2026 and the second notice on 31st March 2026. These contain details of the examinations and assessments.

All notices for 2026 examinations are on-line at

<https://www.maths.ox.ac.uk/members/students/undergraduate-courses/teaching-and-learning/part-c-students/examinations-and-assessments/part-c-and-omms>.

The 2026 examination conventions are available at

<https://courses.maths.ox.ac.uk/mod/book/view.php?id=65654>.

Part II

A1. General Comments on the Examination

The examiners would like to convey their grateful thanks for their help and cooperation to all those who assisted with this year's examination, either as assessors or in an administrative capacity.

In addition the internal examiners would like to express their gratitude to Prof Rosemary Dyson and Prof Roger Moser for carrying out their duties as external examiners in a constructive and supportive way during the year, and for their valuable input at the final examiners' meetings.

Timetable

The examinations began on Monday 1st June and finished on Friday 12th June.

Mitigating Circumstances Notice to Examiners and other special circumstances

A subset of the examiners (the 'Mitigating Circumstances Panel') attended a pre-board meeting to band the seriousness of the individual notices to examiners. The outcome of this meeting was relayed to the Examiners at the final exam board, who gave careful regard to each case, scrutinised the relevant candidates' marks and agreed actions as appropriate.

Setting and checking of papers and marks processing

Following established practice, the questions for each paper were initially set by the course lecturer, with the lecturer of a related course involved as checker 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 where necessary. The revised questions were then sent to the external examiners. Feedback from external examiners was given to examiners, and to the relevant assessor for each paper for a response. The internal examiners met a second time late in Hilary Term to consider the external examiners' comments and assessor responses. The cycle was repeated for the Hilary Term courses, with the examiners' meetings in the Easter Vacation. Before questions were submitted to the Examination Schools, setters were required to sign off a camera-ready copy of their questions.

Exams were held in-person in the Exams Schools. Papers were collected by the Academic Administration team and made available to assessors approximately half a day following the examination. Assessors were made aware of the marking deadlines ahead of time and all scripts and completed mark sheets were returned, if not by the agreed due dates, then at least in time for the script-checking process.

A team of graduate checkers, under the supervision of Anwen Amos, reviewed the mark sheets 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. Sub-totals for each part were also checked against the mark scheme, noting correct addition. In this way a number of errors were corrected, with each change approved by one of the examiners who were present throughout the process.

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 examiners followed established practice in determining the University standardised marks (USMs) reported to candidates. This leads to classifications awarded at Part C broadly reflecting the overall distribution of classifications which had been achieved the previous year by the same students.

For details on the scaling process please see the Mathematical Institute's website where it is outlined in full: [Determination of University Standardised Marks](#).

A preliminary meeting of the internal examiners was held in advance of the final exam board meeting to compare the default settings produced by the algorithm alongside the reports from assessors. It was agreed that only a selection of scaling maps would be further reviewed at the final exam board, and that external examiners would be given an opportunity to review all maps prior to the meeting. Adjustments were made to the default settings as appropriate, paying particular attention to borderlines and to raw marks which were either very high or very low. Where the examiners were in doubt as to the most appropriate scaling, the preliminary scalings were passed over to the final exam board meeting, where the factors considered by those in the preliminary meeting were reviewed and weighed before a final decision was made.

Table 3 on page 5 gives the final positions of the corners of the piecewise linear maps used to determine USMs.

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

Table 3: Vertex positions for the piecewise linear scaling maps, P_1 , P_2, P_3 with the raw marks rescaled to be out of 50. The difficulty score for each paper is also given.

Paper	P_1	P_2	P_3	Additional corners	Difficulty score
C1.1	11.38;37	22.97;64.5	31.77;69.5	40.89;80 ; 50;100	0.23
C1.2	15.76;37	31.82;64.5	40.62;69.5	45.31;80 ; 50;100	-8.62
C1.3	14;50	20.67;64.5	29.47;69.5	39.74;80 ; 50;100	2.53
C1.4	11.98;37	24.19;64.5	32.99;69.5	41.5;80 ; 50;100	-0.99
C2.2	12.21;37	24.65;64.5	33.45;69.5	41.73;80 ; 50;100	-1.45
C2.4	10.37;37	20.94;64.5	29.74;69.5	39.87;80 ; 50;100	2.26
C2.5	11.04;37	22.28;64.5	31.08;69.5	40.54;80 ; 50;100	0.92
C2.7	5.28;37	10;50	20;69.5	33;80 ; 50;100	12.55
C3.1	14.93;37	30.13;64.5	38.93;69.5	44.47;80 ; 50;100	-6.93
C3.10	7.91;37	15.96;64.5	24.76;69.5	37.38;80 ; 50;100	7.24
C3.11	12.29;37	24.8;64.5	33.6;69.5	41.8;80 ; 50;100	-1.6
C3.12	8.34;37	18;60	25.64;69.5	37.82;80 ; 50;100	6.36
C3.2	11.81;37	23.83;64.5	32.63;69.5	41.32;80 ; 50;100	-0.63
C3.3	12;50	23.24;64.5	32.04;69.5	41.02;80 ; 50;100	-0.04
C3.4	12.34;37	24.9;64.5	33.7;69.5	41.85;80 ; 50;100	-1.7
C3.5	12.98;37	26.2;64.5	35;69.5	42.5;80 ; 50;100	-3
C3.6	13.51;37	27.27;64.5	36.07;69.5	43.04;80 ; 50;100	-4.07
C3.7	13.76;37	27.77;64.5	36.57;69.5	43.29;80 ; 50;100	-4.57
C3.8	8.95;37	26.86;69.5	38.43;80	; 50;100	5.14
C4.1	10.31;37	20.81;64.5	29.61;69.5	39.81;80 ; 50;100	2.39
C4.3	9.54;37	19;55	28.06;69.5	40;82 ; 50;100	3.94
C4.6	12.38;37	24.99;64.5	33.79;69.5	41.9;80 ; 50;100	-1.79
C4.9	13.84;37	27.94;64.5	36.74;72	43.37;80 ; 50;100	-4.74
C5.1	10.91;37	22.03;58	30.83;69.5	40.42;80 ; 50;100	1.17
C5.11	11.21;37	28.63;64.5	31.43;69.5	40.72;80 ; 50;100	0.57
C5.12	12.33;37	24.88;64.5	33.68;69.5	41.84;80 ; 50;100	-1.68
C5.2	11.86;37	23.93;60	32.73;69.5	41.37;80 ; 50;100	-0.73
C5.5	10.09;37	17;50	26;65	29.17;69.5 ; 39.59;80 ; 50;100	2.83
C5.6	13.17;37	25;50	35.39;69.5	42.7;80 ; 50;100	-3.39
C5.7	9.98;37	20.14;58	28.94;69.5	39.47;80 ; 50;100	3.06
C5.9	11.96;37	20;53	32.94;69.5	41.47;80 ; 50;100	-0.94
C6.1	10.53;37	20;58	30.05;69	40.03;80 ; 50;100	1.95
C6.2	11.07;37	24;63.5	31.14;69.5	40.57;80 ; 50;100	0.86
C6.4	11.17;37	22;60	31.35;69.5	40.68;80 ; 50;100	0.65
C7.4	14.64;37	29.55;64.5	38.35;69.5	44.18;80 ; 50;100	-6.35
C7.5	10.15;37	23;50	29.29;69.5	39.65;80 ; 50;100	2.71
C7.7	11.46;37	23.14;64.5	31.94;69.5	40.97;80 ; 50;100	0.06
C8.1	9.88;37	19.94;64.5	28.74;69.5	39.37;80 ; 50;100	3.26
C8.2	11.22;37	22.65;64.5	31.45;69.5	40.73;80 ; 50;100	0.55
C8.3	14.36;37	28.98;64.5	37.78;69.5	40;72 ; 43.89;80 ; 50;100	-5.78
C8.4	13.66;37	27.57;64.5	36.37;69.5	43.19;80 ; 50;100	-4.37
C8.7	11.98;37	24.18;64.5	32.98;69.5	41.49;80 ; 50;100	-0.98

Paper	P_1	P_2	P_3	Additional corners	Difficulty score
SC1	12.45;37	25.13;64.5	33.93;69.5	41.97;80 ; 50;100	-1.93
SC2	13.58;37	27.42;64.5	36.22;69.5	43.11;80 ; 50;100	-4.22
SC4	12.76;37	27;64.5	36;69.5	42.28;80 ; 50;100	-2.56
SC5	9.87;37	19.93;64.5	28.73;69.5	39.37;80 ; 50;100	3.27
SC6	13.98;37	28.22;64.5	37.02;69.5	43.51;80 ; 50;100	-5.02
SC7	12.35;37	24.93;64.5	33.73;69.5	41.87;80 ; 50;100	-1.73
SC9	9.91;37	20.01;64.5	28.81;69.5	39.41;80 ; 50;100	3.19
SC10	11.29;37	22.79;64.5	31.59;69.5	40.8;80 ; 50;100	0.41
SC11	8.95;37	18.06;64.5	26.86;69.5	38.43;80 ; 50;100	5.14

B. Equality and Diversity issues and breakdown of the results by gender

Table 5: Breakdown of results by gender

Number						
Year	Gender	Distinction	Merit	Pass	Fail	Total
2026	Female	12	2	4	0	18
2026	Male	34	15	14	1	68
2026	Total	46	17	18	1	86
2025	Female	12	6	3	0	21
2025	Male	45	15	10	3	73
2025	Total	57	21	13	3	94
2024	Female	11	9	3	0	23
2024	Male	60	17	7	0	84
2024	Total	71	26	10	0	107
2023	Female	7	8	3	0	18
2023	Male	54	13	9	0	76
2023	Total	61	21	12	0	94
2022	Female	10	9	5	0	24
2022	Male	36	10	9	0	55
2022	Total	46	19	14	0	79
2021	Female	15	8	5	1	29
2021	Male	45	12	13	1	71
2021	Total	60	20	18	2	100
Percentage						
Year	Gender	Distinction	Merit	Pass	Fail	Total
2026	Female	66.67	11.11	22.22	0	100
2026	Male	55.88	22.06	20.59	1.47	100
2026	Total	58.14	19.77	20.93	4.65	100
2025	Female	57.14	28.57	14.29	0	100
2025	Male	61.64	20.55	13.70	4.11	100
2025	Total	60.64	22.34	13.83	3.19	100
2024	Female	47.83	39.13	13.04	0	100
2024	Male	71.43	20.24	8.33	0	100
2024	Total	66.36	24.30	9.35	0	100
2023	Female	38.89	44.44	16.67	0	100
2023	Male	71.05	17.11	11.84	0	100
2023	Total	64.89	22.34	12.77	0	100
2022	Female	40.00	36.00	20.00	0	100
2022	Male	65.45	18.18	16.36	0	100
2022	Total	58.23	24.05	17.72	0	100
2021	Female	51.72	27.59	17.24	3.45	100
2021	Male	63.38	16.90	18.31	1.41	100
2021	Total	60.00	20.00	18.00	2.00	100

Table 6: Breakdown of results by gender (pre-2021 classification)

[illegible]

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

Data for papers with fewer than six candidates are not included in the public versions of the examiners' report.

Table 7: Numbers taking each paper

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
C1.1	(-)	(-)	(-)	(-)	(-)
C1.2	(-)	(-)	(-)	(-)	(-)
C1.3	11	29.64	11.1	71	12.7
C1.4	10	34.8	7.05	73.8	8.74
C2.2	9	36.5	10.38	68.44	29.15
C2.4	(-)	(-)	(-)	(-)	(-)
C2.5	(-)	(-)	(-)	(-)	(-)
C2.7	16	22.88	6.93	70.31	8.71
C3.1	18	39.78	8.6	76.22	14.09
C3.10	(-)	(-)	(-)	(-)	(-)
C3.11	(-)	(-)	(-)	(-)	(-)
C3.12	(-)	(-)	(-)	(-)	(-)
C3.2	11	33.4	8.33	66.45	23.75
C3.3	13	36	7.11	75.77	8.65
C3.4	(-)	(-)	(-)	(-)	(-)
C3.5	(-)	(-)	(-)	(-)	(-)
C3.6	(-)	(-)	(-)	(-)	(-)
C3.7	11	34.22	11.86	57.82	33.15
C3.8	10	25.9	12.69	65.2	18.8
C4.1	13	28.38	7.84	69.38	8.23
C4.3	10	28.3	9.9	67.8	14.34
C4.6	(-)	(-)	(-)	(-)	(-)
C4.9	(-)	(-)	(-)	(-)	(-)
C5.1	14	30.57	6.03	68.43	7.62
C5.11	26	31.19	7.43	68.04	11.18
C5.12	17	34	5.72	71.35	6.01
C5.2	18	32.78	8.11	69.67	11.37
C5.5	33	30.21	8	69.39	10.92
C5.6	22	36.09	6.86	70.14	11.81
C5.7	25	28.83	7.68	65.76	16.54
C5.9	(-)	(-)	(-)	(-)	(-)
C6.1	10	30.5	8.75	69.6	12.65
C6.2	9	29	6.85	59.78	23.75
C6.4	(-)	(-)	(-)	(-)	(-)
C7.4	(-)	(-)	(-)	(-)	(-)
C7.5	(-)	(-)	(-)	(-)	(-)
C7.7	11	31.73	4.94	70.27	4.47
C8.1	13	30.33	4.6	66.23	20.28

Paper	Number of Candidates	Avg RAW	StDev RAW	Avg USM	StDev USM
C8.2	10	34	9.77	66.4	25.91
C8.3	10	39.7	6	75.8	12.36
C8.4	9	38.5	7.43	68	28.24
C8.7	9	33.78	12.21	71.56	16.68
SC1	(-)	(-)	(-)	(-)	(-)
SC2	(-)	(-)	(-)	(-)	(-)
SC4	(-)	(-)	(-)	(-)	(-)
SC5	(-)	(-)	(-)	(-)	(-)
SC6	(-)	(-)	(-)	(-)	(-)
SC7	(-)	(-)	(-)	(-)	(-)
SC9	(-)	(-)	(-)	(-)	(-)
SC10	(-)	(-)	(-)	(-)	(-)

Table 9: *

Table 8: Statistics by paper (USM only assessments)

Paper	Number of Candidates	AvgUSM	StdevUSM
C2.3	(-)	(-)	(-)
C2.6	(-)	(-)	(-)
C3.9	8	79.75	12.53
C4.7	(-)	(-)	(-)
C5.4	11	64	9.15
C6.5	15	67.87	2.95
C7.1	(-)	(-)	(-)
CCD	81	72.11	8.56
CCS1	(-)	(-)	(-)
COD	(-)	(-)	(-)
CS1	(-)	(-)	(-)

The tables that follow give the question statistics for each paper for Mathematics candidates. Data for papers with fewer than six candidates are not included in the public version of the report.

Paper C1.1: Model Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	20	20	4.69	4	0
Q2	8.33	8.33	4.73	3	0
Q3	17	17		1	0

Paper C1.2: Gödel's Incompleteness Theorems

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19	20.67	4.08	3	1
Q2	19.8	20.5	4.82	4	1
Q3	21.71	21.71	2.56	7	0

Paper C1.3: Analytic Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.8	15.8	7.25	10	0
Q2	17	17	3.74	6	0
Q3	11	11	5.44	6	0

Paper C1.4: Axiomatic Set Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.29	17.29	3.25	7	0
Q2	17.89	18.75	3.89	8	1
Q3	15.4	15.4	5.94	5	0

Paper C2.2: Homological Algebra

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.67	17.67	4.5	6	0
Q2	19.25	19.25	5.12	8	0
Q3	16	16	11.31	2	0

Paper C2.4: Infinite Groups

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14	14	6.96	6	0
Q2	17.5	17.5	5.88	8	0
Q3	16.5	16.5	7.78	2	0

Paper C2.5: Non-Commutative Rings

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.5	16.5	5.07	4	0
Q2	14.33	14.33	5.51	3	0
Q3	19.67	19.67	4.62	3	0

Paper C2.7: Category Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	8.55	9.22	4.03	9	2
Q2	10.12	10.12	4.91	8	0
Q3	13.47	13.47	3.64	15	0

Paper C3.1: Algebraic Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19.72	19.72	4.23	18	0
Q2	14	14	2.83	2	0
Q3	20.81	20.81	4.43	16	0

Paper C3.2: Geometric Group Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.67	16.67	4.06	9	0
Q2	12.86	14.67	7.45	6	1
Q3	19.2	19.2	3.42	5	0

Paper C3.3: Differentiable Manifolds

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.7	17.11	5.85	9	1
Q2	14.17	16.2	6.21	5	1
Q3	19.42	19.42	5.12	12	0

Paper C3.4: Algebraic Geometry

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	21	21	0	2	0
Q2	20	20		1	0
Q3	11	11		1	0

Paper C3.5: Lie Groups

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.43	17.43	4.35	7	0
Q2	18.38	18.38	4.21	8	0
Q3	22	22		1	0

Paper C3.6: Modular Forms

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.67	17.67	7.02	3	0
Q2	12	12		1	0
Q3	12	12	11.31	2	0

Paper C3.7: Elliptic Curves

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13.5	13.5	7.59	4	0
Q2	17	17	6.41	8	0
Q3	19.67	19.67	6.38	6	0

Paper C3.8: Analytic Number Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	10	10	6.81	6	0
Q2	13.62	15.57	8.88	7	1
Q3	11.88	12.86	7.04	7	1

Paper C3.10: Additive and Combinatorial Number Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12.33	12.33	3.01	6	0
Q2	11.67	11.67	5.13	3	0
Q3	12.2	12.2	5.31	5	0

Paper C3.11: Riemannian Geometry

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16	16	6.22	7	0
Q2	16	16		1	0
Q3	19	19	4.34	6	0

Paper C3.12: Low-Dimensional Topology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	7.33	7.33	5.03	3	0
Q2	12	12	4.08	4	0
Q3	20	20		1	0

Paper C4.1: Further Functional Analysis

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.8	15.8	4.34	10	0
Q2	12.91	12.91	3.99	11	0
Q3	13.8	13.8	5.93	5	0

Paper C4.3: Functional Analytical Methods for PDEs

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13.29	13.29	3.04	7	0
Q2	15.14	15.14	5.4	7	0
Q3	14	14	6.9	6	0

Paper C4.6: Fixed Point Methods for Nonlinear PDEs

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17	17	4.58	3	0
Q2	17.6	17.6	3.05	5	0
Q3	19.5	19.5	6.36	2	0

Paper C4.9: Optimal Transport and Partial Differential Equations

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	21	21	4.24	2	0
Q2	17	17	0	2	0
Q3	19.75	19.75	4.35	4	0

Paper C5.1: Solid Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.07	18.07	2.95	14	0
Q2	15.25	17.67	4.99	3	1
Q3	10.23	11.09	4.75	11	2

Paper C5.2: Elasticity and Plasticity

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.53	14.93	5.46	14	1
Q2	16.88	16.88	3.72	8	0
Q3	16.6	17.57	5.26	14	1

Paper C5.5: Perturbation Methods

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.1	16.84	4.99	19	1
Q2	15.1	15.55	5.99	29	1
Q3	10.74	12.56	5.38	18	5

Paper C5.6: Applied Complex Variables

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19.67	20.82	5.34	17	1
Q2	15.1	15.1	5.11	10	0
Q3	16.17	17	5.88	17	1

Paper C5.7: Topics in Fluid Mechanics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	16.33	16.33	4.68	24	0
Q2	12.82	12.82	3.74	22	0
Q3	7.67	9	2.31	2	1

Paper C5.9: Mathematical Mechanical Biology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.33	15.33	1.53	3	0
Q2	18.4	18.4	3.78	5	0
Q3	12.5	12.5	7.33	4	0

Paper C5.11: Mathematical Geoscience

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.1	17.1	3.11	20	0
Q2	11.65	13.53	6.87	17	3
Q3	15.93	15.93	4.92	15	0

Paper C5.12: Mathematical Physiology

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	18.56	18.56	3.05	16	0
Q2	14.75	14.75	3.68	16	0
Q3	18.67	22.5	6.81	2	1

Paper C6.1: Numerical Linear Algebra

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15.14	15.14	5.58	7	0
Q2	12.11	16.67	7.83	6	3
Q3	14.14	14.14	2.85	7	0

Paper C6.2: Continuous Optimization

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.86	14.86	3.18	7	0
Q2	12.33	12.33	5.51	3	0
Q3	14.29	15.17	4.07	6	1

Paper C6.4: Finite Element Methods for Partial Differential Equations

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	-	-	-	-	-
Q2	15.6	15.6	7.96	5	0
Q3	18.8	18.8	3.9	5	0

Paper C7.4: Introduction to Quantum Information

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19.67	19.67	1.37	6	0
Q2	13.4	13.4	5.73	5	0
Q3	19	19	1	3	0

Paper C7.5: General Relativity I

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13	13		1	0
Q2	9	9		1	0
Q3	13.5	13.5	3.54	2	0

Paper C7.7: Random Matrix Theory

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.5	17.5	3.6	10	0
Q2	12	15	6.56	2	1
Q3	14.4	14.4	4.58	10	0

Paper C8.1: Stochastic Differential Equations

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.4	17.4	3.37	10	0
Q2	12.9	12.9	2.77	10	0
Q3	15.25	15.25	3.86	4	0

Paper C8.2: Stochastic Analysis and PDEs

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	10	10	5.66	2	0
Q2	18.56	18.56	4.67	9	0
Q3	17	17	5.72	7	0

Paper C8.3: Combinatorics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19.2	19.2	5.12	5	0
Q2	20.7	21.67	4.3	9	1
Q3	17.67	17.67	1.75	6	0

Paper C8.4: Probabilistic Combinatorics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	20.86	20.86	2.91	7	0
Q2	12.67	12.67	1.53	3	0
Q3	20.67	20.67	4.03	6	0

Paper C8.7: Optimal Control

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14.88	14.88	6.62	8	0
Q2	8.25	14.5	8.54	2	2
Q3	19.5	19.5	8.64	8	0

Paper SC1: Stochastic Models in Mathematical Genetics

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13.67	13.67	5.86	3	0
Q2	21.33	21.33	4.03	6	0
Q3	20.67	20.67	3.21	3	0

Paper SC2: Probability and Statistics for Network Analysis

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12.5	19	9.19	1	1
Q2	12	12		1	0
Q3	12.5	12.5	0.71	2	0

Paper SC4: Statistical Data Mining and Machine Learning

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	19.33	19.33	2.73	6	0
Q2	14.5	14.5	7.14	4	0
Q3	24.5	24.5	0.71	2	0

Paper SC5: Advanced Simulation Methods

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	12			0	1
Q2	16	16		1	0
Q3	13	13		1	0

Paper SC6: Graphical Models

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	13			0	1
Q2	18	18		1	0
Q3	15	15		1	0

Paper SC7: Bayes Methods

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	14			0	1
Q2	18	18		1	0
Q3	20	20		1	0

Paper SC9: Interacting Particle Systems

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	17.2	17.2	1.79	5	0
Q2	15.67	15.67	1.53	3	0
Q3	17	17	1.41	2	0

Paper SC10: Algorithmic Foundations of Learning

Question	Mean Mark		Std Dev	Number of attempts	
	All	Used		Used	Unused
Q1	15	15	6.93	1	0
Q2	17	17		3	0
Q3	20.5	20.5	2.12	2	0

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

The exam board resolutely recommends that the department carries out a full review of the impact of AI on submitted coursework. In particular the examiners resolutely recommend a review of the dissertations scheme.

As currently constituted, dissertations cannot continue considering the potential for students to utilise AI and the department's inability to recognise and penalise such instances. The examiners strongly recommend that Teaching Committee discontinue the dissertations unless the following can be put into place:

1. Oral examinations Due to AI, dissertations are not effective summative assessments at present; the department should take action to make them better formative assessments by introducing presentations that give thorough feedback. The examiners propose that the oral examinations are held going forward. These should take place after the submission deadline and provide the department with the opportunity to confirm the student's understanding of their dissertation. It was noted that there are logistical difficulties to address:
 - The pool of assessors. The suitability of having the supervisor as an assessor was raised. Prof Manolopoulou noted that UCL require their supervisors to submit 5 questions in advance in place of them assessing the oral examination.
 - Due to the potential increase in workload for faculty and postdocs, it was felt that PhD students should be permitted to act as assessors, although it was noted that the University discourages PhD students from acting as such.
 - Format of the examination. It was suggested that they could consist of a Q&A session in place of a longer presentation.
 - Marking. Whether the oral examination will standalone or combine with the project mark will need to be finalised.
2. Students should be required to submit a draft or sample of their dissertation prior to the submission deadline. There should be the expectation that the supervisor should read a draft of the dissertation. The examiners propose that this should take place prior to a final supervision meeting where the supervisor would have the opportunity to raise any concerns with the student. This meeting should take place allowing sufficient time for the student to address any feedback before the submission deadline. This would enable supervisors to have more control over the student's work.
3. Increased supervision hours and mandatory supervision meetings To ensure effective oversight, students must be required to attend supervision meetings.
4. Increased Teaching Stint. To make the dissertation more attractive to supervisors, stint must be increased to reflect the true workload. It is not feasible to continue the dissertations without a complete overhaul. The examiners hope that increased oversight through higher supervision hours, oral examinations and a review of a draft submission would help to ensure that the relevant competencies have been validly assessed, despite changes in the way students carry out the work. If these changes are not possible the examiners recommend that the dissertations should be discontinued.

Similarly, to mitigate against the impact of AI, the examiners would encourage Teaching Committee to discontinue utilising mini-projects as a form of assessment. The examiners noted the recommendation of the work that Professor Michael Grove from the University of Birmingham has carried out on how to support students to use AI positively.

The exam board noted that script checking processes identified an increasing volume of marking errors. In particular markers not following the marking guidelines hampered script checking and harmed the robustness of the process.

Additionally, the examiners would welcome a formalisation of the process whereby the exam board can break conventions, to ensure consistency in future years. Specific guidance from Teaching Committee on how to consider borderline cases would be helpful

Finally, the examiners note their concerns with the ambiguity of word count penalty guidance for dissertations. In one case a student had exceeded the word count by 2000 words due to a misunderstanding of whether the appendix should be included. The examiners agreed that the guidance was misleading and would strongly recommend to Teaching Committee that this paragraph is revisited to clarify how appendices should count towards the word count. The examiners recommend that students are no longer permitted to include an appendix in their dissertation, other than in cases where coding is used.

E. Comments on papers and on individual questions

The following comments were submitted by the assessors.

C1.1: Model Theory

Question 1. Q1(a) was done well by most candidates, though many did not give the non-model-complete group example.

The first statement in Q1(b) was a variant of a result in the course and was done well by most. The implication $(ii) \Rightarrow (i)$ in the next part was done well by all, though the reverse implication $(i) \Rightarrow (ii)$ was only correctly proved by a small number of candidates.

Most candidates did well in Q1(c), except for the part on a sentence that is preserved under unions of chains but not substructures, which was done by a few.

Question 2. Q2(a) was done well by most. Many candidates used back-and-forth to prove the first statement in Q2(b) on an atomic model being $\aleph_0$ -homogeneous, listing the elements. This does not work as we are not assuming the structure is necessarily countable. Many did well in the next statement that certain $\aleph_0$ -homogeneous structures are $\aleph_0$ -saturated.

A good number of candidates did the first statement of Q2(c) on the existence of an $\aleph_0$ -saturated model, while most candidates found the next statement that a countable atomic saturated structure is $\aleph_0$ -categorical, more challenging.

A few candidates did part (d), on non-finiteness of the automorphism group of a countably infinite model of an $\aleph_0$ -categorical theory.

Question 3. Most did well in Q3(a)(i) on quantifier-elimination and real semi-algebraic sets, and part (a)(ii) on number of types.

Only a few gave a non-principal type or a proof of $2^{\aleph_0}$ many non-isomorphic countable models in Q3(a)(iii).

Part (b) was done well by all, except that only a few proved that a filter can be extended to an ultrafilter.

Most did well in part (c) on construction of certain ultraproducts of finite fields.

C1.2: Gödel's Incompleteness Theorems

Many good answers were given to question 1.

Part (a) was well done on the whole.

In parts (b), (c) and (d), once one knows that PA is not Σ_2 -complete, it of course follows that Q and R are not. However, the statements " $\leq$ is a total order" (in part (b)) and " $+$ is commutative (in part (c))" are Π_1 and therefore Σ_2 .

One common error made in parts (b) and (c) was not to specify completely the model being constructed by, for example, failing to define multiplication everywhere.

In question 2., there were many good answers to part (a) and quite a few good arguments for part (b). Part (c) was hard and was marked generously.

In question 3., parts (a) and (c) were done well. In part (b), some candidates forgot about the rule of Generalisation. A variety of correct methods were found to do part (d).

C1.3: Analytic Topology

Question 1: Part (a) was done mostly well with the exception of not all candidates reading the question carefully and a large number not being able to show that a product of connected spaces is connected despite this appearing on the problem sheet.

In (b)(i), constructing the inverse limit as a subspace of the product was more difficult than expected. A large number of candidates suggested taking the full product together with the projections which in general fails to have the required commutative diagrams. However, they must have known something was wrong as they did not claim that (b)(ii) then follows trivially from (a).

Once the inverse limit was correctly identified, Hausdorffness, compactness and non-emptiness were usually not a problem. However, proving its connectedness was too difficult for almost all of these candidates as well.

Both the trivial example as well as non-trivial examples were given in (iii).

Question 2: Generally well done. The majority of marks was lost due to not checking one of the many required statements, none of which were difficult.

The only (occasional) trouble with part (a) was compactness of the Stone Space. In part (b) not all candidates verified that the obvious map was open onto its image. In part (c) the main gap was verifying that the image of $\mathcal{SP}(\mathbb{N})/\text{fin}$ under $\mathcal{S}g$ was indeed the remainder. Part (d) stumped almost all candidates.

Question 3: Most attempts at this question were disappointing:

A large number of candidates struggled to complete (a)(i), the second half of the proof of Urysohn's Lemma. Some progress was made on (a)(ii) but despite this being a very minor variation on a question on Problem Sheet 2, no candidate gave a fully correct proof and almost no-one even attempted an inductive construction of the U_q satisfying part (i).

Part (b)(i) was done well, although in proving continuity of u not all candidates realised that it is not globally a finite sum but of continuous functions but only locally. In (ii) most candidates did not apply the hint twice but only once and thus their suggested set of functions did not have locally finite support. A lot of candidates did not even start part (iii).

C1.4: Axiomatic Set Theory

This paper was difficult on the whole.

In question 1., many candidates did part (a) successfully. The words “very briefly” meant that candidates needed to give the most important steps in the proof, of which the Condensation Lemma was one. The required result does not follow from the existence of a definable well-ordering of the universe.

Part (b) was done well on the whole.

Part (c) was found to be difficult. Many students, who did not succeed with the rest of the argument, did perform the deduction in the last sentence, and so got some marks. The method envisaged was similar to that in part (a): a suitable elementary substructure of a suitable L_β is found, and then its Mostowski collapse is computed.

In question 2., part (a) was done well by many candidates, and there were quite a few correct solutions to part (b) and to part (c).

Few candidates found a way to use (c)(ii) to do part (d).

In question 3., part (a) was done well by many candidates, though some neglected to say why the transitive closure, as they defined it, was actually a set. Many candidates were successful with part (b) also.

Part (c) presented a varied picture. Some candidates got the right answer for part (i), and quite a few did not. The easiest way may be to begin with instances of Replacement involving operators from ordinals to the class of ordinals; a condition on κ then emerges; and one can then prove that this condition is sufficient in general. The answer to part (ii) surprised some who found it, reasonably enough. Part (iii) can be found by a fixed-point-type argument. Quite a few candidates got the wrong answer to part (iv); examination of a solution to part (iii) could have indicated what the correct answer to (iv) was and why.

C2.2: Homological Algebra

Most candidates attempted Q1. Part (a) was bookwork. Part (b) (i) and (ii) were very similar to problems discussed in the lectures. (b)(iii) was similar to problems on the problem sheets and (b)(iv) followed from the previous one using a long exact sequence. Part (c) was new but quite similar to a problem on the problem sheets. Many candidates did well on this

question. Knowing the bookwork well was very useful. Most candidates attempted Q2. Part (a) was bookwork. Part (b) was similar to calculations in lectures using Koszul complexes. Part (c) was new and required noticing that tensoring a projective resolution with an algebra which is flat as a module gives a projective resolution. Many candidates did well on this question. Knowing the bookwork well was very useful. Some candidates attempted Q3. Part (a) was bookwork. Part (b)(i) was bookwork and (b)(ii) was similar to what was discussed in lectures. Part (c) was new and required noticing that the tensor product of two free resolutions is free and then applying the 1Kunneth formula for complexes. The majority of candidates who attempted this question did well on it, and also here knowing the bookwork well was very useful.

C2.4: Infinite Groups

Question 1. Most students attempted this question. 1ai, aii were generally well done. The first part of 1aiii was well done but only few students managed to give a valid presentation for the second part. For bi most candidates gave a valid group presentation to the wreath product but often did not give a correct argument that it is an isomorphism. 1bii was well done with most candidates noting the existence of a subgroup that is not f.g. Many students managed to show the existence of a homomorphism but some missed points for not explaining clearly why the relators map to 1. The last part was done by very few candidates.

Question 2. Many students attempted this question. 2ai, aii were well done. For aiii some students did not realize they needed to induct and use the second term of the lower central series. 2aiv was generally well done. For 2av some students did not properly justify why the map is an isomorphism. For the last part some candidates failed to explain how to pick an appropriate homomorphism. 2bi was generally well done even though some candidates got lost in the notation for semi-direct products and gave incomplete arguments. For 2bii many students had the right idea but fewer managed to identify correctly the subgroups N, Z . A small number of candidates managed to solve 2biii realizing the relevance of 2av and providing an elegant argument.

Question 3. Fewer students attempted this question. 3ai and the first part of 3aii were well done but many candidates did not manage to give the inequality for finite index subgroups. Some correctly started by taking a generating set that included coset representatives but did not go further. For 3aiii most candidates gave a correct argument that the group is of exponential growth but approximately half gave the wreath product example expected. For 3bi the arguments on the presentation part were often incomplete as in 1biii. Most students did well in the latter part and even students that did not complete the argument got some partial credit as they correctly tried to rewrite words giving a bound on the word length. Only one student gave a nearly complete answer for 3bii.

C2.5: Non-Commutative Rings

The overall performance of the candidates was similar to past years with 12-15 marks per question available for bookwork and seen material, and getting progressively harder for the last 10 marks on new material.

Question 1 was popular, with good answers to (a) and (b)(i)-(iii), though only one candidate gave a satisfactory answer to (b)(iv).

Question 2 was also attempted by most candidates with good answers to (a) (bookwork) and (b)(i) which was similar to questions in problem sheets. No one managed a complete solution to (b)(ii), there were several attempts on the right track.

Question 3 was least popular but with good answers overall. Only (d) posed a difficulty to the candidates and several found the solution following the suggested route.

C2.7 Category Theory

The overall performance of the students was disappointing: either this paper was too difficult, or the students were generally unprepared.

Q1 exhibited the worst general performance (compared to Q2 and Q3). Almost no one was able to answer a(ii) or b(i) correctly, which was very disappointing given how basic these questions were. Similarly, not a single person was able to solve b(iii). To give a sense of the scale of the disaster: 95% of people who attempted Q1 got less than half the points.

Q2 I was extremely disappointed by how few people were able to answer a(i) β , given that this is very much a bookwork question (it asks to describe colimits in the category of groups). People did ok at b(i) and b(ii). Very few people were able to do a(iii), but that was expected, as that question was quite difficult.

Q3 Again, Highly disappointing performance at a(i). The questions b(i) and b(ii) turned out to be easier than expected, an many people did well at those. The questions c(i) – c(iii) were done reasonably well.

C3.1: Algebraic Topology

Question 1 (34 attempts): This question tested knowledge of basic definitions in homology theory, the long exact sequence of a pair, and the Mayer–Vietoris long exact sequence. The general level of solutions was high. Part (a)(i) was generally fine, though some candidates forgot to state that $\partial_i \circ \partial_{i+1} = 0$ in a chain complex or forgot to define the homology of a chain complex. In (a)(ii), most candidates wrote down the general definition for the connecting map (which was accepted with full marks), but in this case it is simply the boundary of a relative cycle in A . In (a)(iii), some candidates did not define the maps in the Mayer–Vietoris sequence. Solutions for (b) were generally correct, with some candidates not discussing what happens at the lower end of the Mayer–Vietoris long exact sequence. Some candidates avoided having to look at distinct cases by using reduced homology. About half the candidates solved (c), using the fact that this is a good pair. There were some attempts to use the long exact sequence of a pair, with only very few complete solutions along these lines, given the technical difficulties.

Question 2 (7 attempts): This question tested knowledge of CW complexes and cellular homology. The general level of solutions was mixed. In (a)(i), few candidates managed to give a full definition of a CW complex. In (a)(ii), nobody managed to state the closure-finite property, nor prove it. There were several correct solutions for (b)(i) and (b)(ii), though there were often some gaps in the definition of the boundary map in cellular homology.

Most solutions for (b)(iii) were correct. There were several almost correct solutions for (c), though most candidates failed to consider the case $m = 0$.

Question 3 (30 attempts): This question tested knowledge of cohomology, Poincaré duality, and the Universal Coefficient Theorem. The general level of solutions was high. Solutions for (a)(i) and (a)(ii) were mostly correct, with occasional minor inaccuracies. The majority of solutions for (a)(iii) were essentially correct, with some candidates not applying the UCT correctly. There were also lots of correct solutions for (a)(iv), with again most issues related to the application of the UCT. Solutions for (b)(i) were largely correct, with some candidates not getting the indices right in the definition of the top and bottom faces in the cup product. Most candidates got the cohomology groups of T^2 right, but some did not fully compute the ring structure. A couple of candidates mixed up the 2-torus with the double torus; they were not penalised for this if the cohomology computation was correct. There were many correct solutions for (b)(iii).

C3.2 Geometric Group Theory

Question 1.

Most students attempted this question.

1ai. Generally well done but some candidates tried to give an informal explanation rather than giving the quotient group.

1aii. The definition of Tietze transformations was generally correct but some students failed to give a precise proof why they don't alter the group. There were many mistakes on the algorithmic part, there were very few complete answers. A common mistake was to try to show that if two groups are isomorphic then there is a finite sequence of Tietze transformation from one to the other (which of course was not the question at all). Some points were taken out when students did not explain how they enumerate all possible moves of a certain type and simply assumed that such an enumeration exists.

1aiii, 1aiv) These parts were done by most candidates. A common mistake was to assume that a homomorphism is an isomorphism.

1bi. Some students assumed that two words are equal in G if and only if they are identical, so their answer in this part was incorrect.

1bii. This part was done by most candidates.

Question 2. A good number of students attempted this question.

2ai. Most students answered this correctly.

2aii. Some students failed to define the action or the edge inclusions correctly. A few assumed that the subgroups A, B were of finite index and received no marks for their answer.

2aiii. The normal form theorem was generally stated correctly. Few students gave a complete answer to the second part although several had the right idea. Some students used an incorrect definition of a normalizer.

2aiv. More than half students gave the correct proof, however a few asserted that if a group does not fix a point then it is free, which is clearly incorrect.

2bi. Most students had the right idea for the first part but few gave a construction of the finite graph and a correct justification of the isomorphism using normal forms.

2bii. Many students started correctly considering the actions of A, B on the tree but very few managed to give a complete argument.

Question 3. A bit less than half of the students attempted this question.

3ai. Generally well done but some students confused slim triangles with thin triangles and missed some marks.

3aii. This was generally well done, even though some students failed to explain that subwords of small length of the word considered representing the identity are geodesic.

3bi. This was done by most students.

3bii. Several students failed to give a finite generating set for H . Some students failed to justify that the word on the given generating set are quasi-geodesic and some tried to give a direct proof of hyperbolicity without using the theorem that quasi-geodesics are close to geodesics (and gave incorrect constants). Very few candidates gave a clear algorithm to find a Dehn presentation even though quite a few had the right start and received partial credit.

C3.3: Differentiable Manifolds

Question 1. In 1(d) students found proving $O(n)$ orientable, and computing the degree, difficult. Successful proofs of orientability either used the exact sequence $0 \rightarrow T_A O(n) \rightarrow M_n(\mathbb{R}) \rightarrow \text{Sym}_n(\mathbb{R}) \rightarrow 0$ for $A \in O(n)$, or noted that as $O(n)$ is a Lie group, left multiplication by A induces an isomorphism $TL_A : T_{\text{Id}} O(n) \rightarrow T_A O(n)$. For the degree, $A \mapsto A^T$ acts as -1 on $T_{\text{Id}} O(n)$, so the degree is $(-1)^{\dim O(n)} = (-1)^{n(n-1)/2}$.

Question 2. For (b), fewer people answered this well than I hoped, as it was an extra question on question sheet 1. Parts (c),(d) were found difficult. Part (c) is geometric, and needs the fact either that $\pi : X \rightarrow X/\Gamma$ is an isomorphism on tangent spaces, or that π identifies small coordinate charts on X with coordinate charts on X/Γ . Part (d) is a purely algebraic consequence of (c), and needs the trick of mapping a k -form α on X to $\frac{1}{|\Gamma|} \sum_{\gamma \in \Gamma} \gamma \cdot \alpha$ to replace α by a Γ -invariant k -form.

Question 3. In (a), to justify that $H^{2n}(\mathbb{CP}^n) \cong \mathbb{R}$ one should say that $\mathbb{CP}^n$ is compact, connected, and oriented. Few people included all three, but I usually gave them the mark anyway.

In (c),(d), the proof involved writing down an explicit form on all of $\mathbb{CP}^n$, when the hint only told you what it was on $U \cap V$. For (c) the answer is

$$\epsilon = \begin{cases} \alpha - d(\eta_U \beta) = d(\eta_V \beta) & \text{on } U \cap V, \\ \alpha & \text{on } V \setminus U, \\ 0 & \text{on } U \setminus V. \end{cases}$$

Then ϵ is smooth and closed and $[\epsilon|_V] = [\alpha - d(\eta_U \beta)] = [\alpha]$ in $H^k(V)$. It is smooth as $\alpha - d(\eta_U \beta) = \alpha$ in $U \cap V$ near $V \setminus U$ as $\eta_U = 0$ there, and $d(\eta_V \beta) = 0$ in $U \cap V$ near $U \setminus V$ as $\eta_V = 0$ there, so the three cases join together smoothly across the junctions. Few people correctly explained how to define ϵ on all of $\mathbb{CP}^n$.

C3.4: Algebraic Geometry

Q1 and Q3 were the most frequently chosen questions. For the smaller number of those who chose Q2, only about a third managed to answer Q2 (c). Very few people managed to answer Q3 (e) correctly. Otherwise, all the parts of the exam were treated equally well by most people.

C3.5: Lie Groups

Question 1: This question was attempted by the majority of candidates and was, overall, the most successful question on the paper. Candidates generally demonstrated a strong command of the relevant bookwork. A common error was an imprecise definition of a Lie subgroup, with some candidates referring to smooth maps from sets that had not yet been endowed with a manifold structure. Part (b) was generally answered well, with most candidates able to apply the relevant concepts correctly. Part (b)(iv), however, proved significantly more challenging, as it required candidates to construct an example that had not been encountered in lectures or examples sheets. Only two of the strongest candidates were able to solve this part completely. Part (c) was also handled well by most candidates, with many producing clear and accurate solutions. Overall, performance on this question was strong across the cohort.

Question 2: This question was also attempted by most candidates. As in Question 1, candidates generally displayed a good knowledge of the core definitions and results from the course. The most common bookwork error was an incomplete definition of an irreducible representation, with some candidates omitting the requirements that the invariant subspace be both proper and non-zero. Part (b) was completed successfully by the majority of candidates and attracted many high marks. Part (c) was the most demanding section of the question, requiring candidates to apply ideas from representation theory in a less familiar setting. The initial parts of (c) were generally answered well, but the later subparts increased gradually in difficulty and effectively differentiated between candidates. Only the strongest candidates were able to make substantial progress through the entire section. In particular, no candidate produced a complete solution to part (v), which was intentionally designed to be challenging. Nevertheless, several of the best candidates made non-trivial progress and demonstrated a clear understanding of the ideas required to reach a full solution.

Question 3: This question was attempted by only three candidates, likely because it covered material introduced towards the end of the course. Two of the three candidates completed almost the entire question and performed very well. However, no candidate was able to provide a complete solution to part (b)(iv).

Summary: Most candidates successfully solved a substantial proportion of the questions they attempted. A noticeable pattern was that candidates tended to achieve similar marks on the two questions they chose to answer, suggesting a fairly consistent level of performance across their selected questions.

C3.6: Modular Forms

Overall a somewhat harder examination paper than usual. Question 1 was fairly predictable and routine, and done very well by (presumably) those students who had been attending

the lectures and classes. I was surprised that Question 3 was much more popular than Question 2, as the latter seemed somewhat more straightforward to me. There were some good attempts at both these questions, though no one got full marks on either.

Question 1: Attempted by all the candidates and done well on by the majority. It is similar in content to the first question on other recent papers.

Question 2: The first half essentially bookwork, with the second half less familiar but not that difficult.

Question 3: This is mainly “modified bookwork”, in which you have to carefully keep track of some auxiliary data. It included in a different context a small piece of number theoretic bookwork from a different part of the course. I think quite a hard question to get full marks on (as shown by marks obtained).

C3.7: Elliptic Curves

Question 1 This question on formal groups was attempted by a relatively small number of candidates and there were only a few good attempts. The candidates who seemed comfortable with the formal groups material were able to produce good answers.

Question 2 This question on torsion subgroups received many good attempts. There were often some imprecisions in the argument to show that torsion points have integral co-ordinates — for example, not considering separately the case of 2-torsion which doesn’t follow immediately from the lectured results on formal groups. The part covering a simplified version of Lutz–Nagell received good answers, as did the final part on bounding the torsion subgroup in a specific family of curves. The bound asked for was rather weak, so there were various routes available to obtaining a correct proof.

Question 3 The bulk of this question was about an example of 2-descent, and received many excellent answers. There were some imprecisions in the elementary number theory arguments to exclude classes from $C(\mathbb{Q})/2C(\mathbb{Q})$ but many answers got full marks for this part. Most candidates correctly gave $\hat{\phi}(5, 25)$ as an example of a point of infinite order, but one spotted that $(-4, 6)$ is another example.

C3.8 Analytic Number Theory

Q1 (a) I thought this part was covering rather basic material and would therefore be done well, but this was not the case. It was particularly surprising how weak the attempts at (ii) were in general, especially given the hint to use (i). In explaining why $n = (1 * \phi)(n)$ in part (i), a number of candidates appealed to the multiplicativity of ϕ without any justification; these attempts lost one mark.

(b) the entirety of this question was a relatively minor modification of bookwork. However, none of it was actual recall of bookwork. A handful of candidates were able to do almost all of the question, but there were also a lot of very weak attempts.

Q2. This was a question where large parts were fairly minor variations on bookwork, albeit some quite tricky bookwork involving estimates for Mellin transforms. The last part (worth 8 marks) tested understanding to a greater extent. Some candidates got close to full marks on the question, while others made little progress.

Q3. Part (a) was simply bookwork and was done by many candidates. A good number of candidates managed the unseen (b), which required integration by parts. Parts (c) and (d) were variations on a theme from lectures. While some candidates struggled to adapt the arguments from their notes, there were a few complete solutions here.

C3.10: Additive and Combinatorial Number Theory

Overall the exam was a bit too much on the hard end, with an average mark of about 50%. With hindsight it was probably both a little bit too long, and a little bit too difficult; next years setter would be advised to take this into account. Having said that, the exam succeeded in producing a good spread of marks, distinguishing between candidates who had a strong grasp of the material, a more basic understanding or those who had struggled to fully digest some of the key concepts.

Question 1 was attempted by a majority of the candidates. The first parts of the question were generally answered quite well, although there were a number of slips on (a)(iii) despite it being very close to things seen multiple times in the notes. Part (b) was generally answered pretty well, but several candidates struggled with the more inventive (b)(ii) and putting everything together in (b)(v). Part (c) was not answered well, perhaps partly because of timing issues.

Question 2 was only attempted by a minority of candidates. Part (a) and (b) were generally answered quite well, with candidates appreciating the core ideas (although several candidates ignored the hinted simplification in (a)(iii) which meant they produced longer answers). Part (c) and (d) were not attempted by many candidates; perhaps this was timing issues arising.

Question 3 was the most popular question. Candidates seemed to have a good general picture for (a) and (b), even if there were occasional failures of execution. Part (c) distinguished well between candidates, but almost no candidate managed to successfully get to a full quantification of (c)(v).

C3.11: Riemannian Geometry

Question 1 This question was on the Riemann curvature tensor and its symmetries. It was very popular, receiving 15 attempts, of which 5 were in the 18-25 mark range. Candidates mostly derived the Bianchi identity correctly and many deduced the fourth curvature symmetry in (c). The last part, essentially showing that sectional curvatures determine the curvature tensor, proved more challenging but a few candidates got this out using the hint. Question 2 Question 2 was on geodesics and the exponential map. It proved less popular, attracting only 7 attempts of which only one was in the 18-25 range. Writing down the equations in terms of Christoffel symbols was generally well done and many (though not all) candidates were fairly confident with the bookwork on the exponential map. Some got the idea that in exponential coordinates the geodesics through the base point were straight lines, hence forcing the vanishing of the Christoffel symbols there. However no one entirely got the last part involving failure of surjectivity for the matrix exponential on $SL(2, \mathbb{R})$ (there were some partial attempts though). Question 3 This question, on the theorems of Myers, Hadamard and Synge, proved very popular, despite being on the most advanced material. There were 15 attempts and 7 were in the 18-25 range. Most candidates could

state the theorems correctly. Applying these theorems in part (b) showed quite a spread of marks, with the most common mistake being to think that a product metric with positively curved factors was itself positively curved. Some candidates however showed a high degree of understanding of how to apply the theorems to solve the problems in part (b).

C3.12: Low-Dimensional Topology and Knot Theory

Question 1 (8 attempts): This question tested knowledge of classical 3-manifold topology, especially the Schönflies theorem and the ‘half lives, half dies lemma’. The general level of solutions was mixed. Part (a)(i) was generally fine. There was no complete solution for (a)(ii), even though this question appeared on Problem Sheet 2. Most solutions were correct for (b)(i), but there was no complete solution for (b)(ii).

Question 2 (7 attempts): This question tested knowledge of knot theory: specifically, the Kauffman bracket, Jones polynomials, Reidemeister moves, and alternating knots. The general level of solutions was mixed. There were no serious issues with part (a). There were several almost correct solutions for (b)(i) and some candidates got the key ideas right for (b)(ii), but there were no complete solutions for (b)(iii) (there were some good observations).

Question 3 (5 attempts): This question tested knowledge of 4-manifolds and the intersection form. The general level of solutions was mixed. Solutions for (a)(i) were mostly correct and several candidates got (a)(ii) essentially right. There were several correct solutions for (b)(i). In (b)(ii), several candidates proved the first part, but nobody showed the curve was connected.

C4.1: Further Functional Analysis

Question 1. A question on the theme of complemented subspaces and sums of closed subspaces. It was a popular question, though the outcome was rather mixed. Most candidates were able to finish the book work in (a). The example in (b) caused problems for about a third of the candidates, which is surprising as it could equally well have appeared in an introductory third year functional analysis course. Very few managed to do all three parts of (c), even though its first part on quotient operators attracted some decent answers.

Question 2. A question on the theme of weak and weak topology. It was the most popular question, but many candidates unfortunately struggled a lot with it. It is remarkable that many candidates had issues already with the book work part in (a) and as a consequence lost, what was supposed to be, easy marks. Part (b) attracted some good solutions, whereas too many candidates tried to solve (c) by quoting the Schur property of ℓ_1 .

Question 3. A question on the theme of compact operators and operators with closed range and finite nullity. This was the least popular question with about a third of the candidates attempting it. Of those most managed the book work part in (a) well. The outcome of part (b), consisting of new examples that can be treated by routine means, was mixed. In some instances, candidates didn’t make a connection with proving finite rank and the observation they made in part (a) about sequential compactness of the closed unit ball and finite dimensionality. Very few candidates managed part (c), though most candidates attempting it had no problem establishing the inequality displayed in (2), only a few progressed any further.

C4.3: Functional Analytic Methods for PDEs

Sixteen students took the examination for the course.

Question 1. This question covered the first part of the course, namely the regularization of L^p functions by convolution, variants of the identity theorem, and a guided proof of Stampacchia's truncation method.

- **Part (a)** consisted primarily of bookwork together with some variations on standard results. Most students answered this part well. Part (iv) was more demanding and was answered successfully by approximately half of the students.
- **Part (b)** concerned variants of the identity theorem. Around half of the students performed well on this part. A common error was to assume that a continuous function which is differentiable almost everywhere must belong to $W^{1,1}$. The Cantor-Vitali staircase function provides a counterexample to this assertion.
- **Part (c)** was a guided proof of Stampacchia's truncation method. Although the question was new, it closely followed material covered in the lectures. A common mistake was to assume that $u \in H_0^1$, which was incompatible with the boundary conditions in the problem.

The question was chosen by ten students. One script was of first-class standard, three were of intermediate standard, three were just above the level of sufficiency, and three were below pass standard, exhibiting serious gaps in basic definitions and foundational results.

Question 2. This question concerned the Gagliardo–Nirenberg–Sobolev inequality and several related inequalities and applications.

- **Part (a)** consisted of standard bookwork and was answered well by most students.
- **Part (b)** concerned variations of the Gagliardo–Nirenberg–Sobolev and Friedrichs inequalities. Approximately half of the students answered this part well.
- **Part (c)** presented a new problem, divided into several accessible subparts. Only one student produced an almost complete solution, although several students successfully completed some of the more straightforward parts.

This was the most popular question, having been chosen by twelve students. Four solutions were of first-class standard (one of them almost perfect), three were of intermediate standard, three were just above the level of sufficiency, and two were below pass standard, exhibiting serious gaps in basic definitions and foundational results.

Question 3. This question concerned the Rellich–Kondrachov compact embedding theorem and an application to an elliptic partial differential equation.

- **Part (a)** consisted largely of bookwork, with a small variation in part (iv). It was answered very well by most students.

- **Part (b)(i)–(ii)** required students to apply the Riesz representation theorem, after showing via ellipticity and Friedrichs’ inequality that the bilinear form associated with the PDE defines an inner product equivalent to the standard inner product on H_0^1 . Most students successfully used this framework to establish existence and uniqueness for the corresponding linear elliptic PDE.
- **Part (b)(iii)** concerned passing to the limit in a sequence of solutions to elliptic PDEs. This was a new problem, based on the Rellich–Kondrachov compactness theorem and elliptic estimates developed during the course. Only one student produced a satisfactory solution. A common mistake was to attempt to pass to the limit in the pairing

$$\langle u_n, v_n \rangle \rightarrow \langle u, v \rangle$$

using only the weak convergences $u_n \rightharpoonup u$ and $v_n \rightharpoonup v$. The key observation is that weak convergence of both sequences is insufficient for this purpose; one must use compactness and elliptic regularity to strengthen at least one of the convergences to strong convergence before passing to the limit.

- **Part (c)** required an application of the Fredholm alternative together with properties of the spectrum of the Laplacian. Approximately half of the students answered this part well.

The question was chosen by ten students. Two solutions were of first-class standard (one almost perfect), four were of intermediate standard, two were just above the level of sufficiency, and two were below pass standard, exhibiting serious gaps in basic definitions and foundational results.

C4.6 Fixed Point Methods for Nonlinear PDEs

Eight students took the examination for the course (a further five DPhil students attended the course as part of their broadening requirement).

Question 1. This question covered the first part of the course, namely Banach’s and Brouwer’s fixed point theorems and null Lagrangians.

- **Part (a)** concerned the statement and proof of Banach’s fixed point theorem (answered perfectly by all students), together with a variant in which the contraction was not uniform. The latter was handled well by most students.
- **Part (b)** concerned Brouwer’s fixed point theorem and a standard application. Both were answered perfectly, or almost perfectly, by every student who attempted the question.
- **Part (c)** concerned null Lagrangians. Part (i) was largely book-keeping and was done well by all students except one. Part (ii) was standard and was answered well by approximately half of the students. Part (iii) was new; no student obtained a complete solution, although one script made substantial progress.

The question was chosen by four students. Of the resulting scripts, one was of first-class standard, one of distinction standard, and two were just above pass level.

Question 2. This question concerned Schauder's fixed point theorem and applications to semi-linear PDEs via the weak maximum principle. It required a solid command of prerequisite material, including Sobolev embeddings and standard properties of the Laplacian.

- **Parts (a) and (b)** were largely bookwork and standard applications. They were answered perfectly, or almost perfectly, by most students. One student omitted the continuity assumption in Schauder's fixed point theorem and chose an unsuitable functional setting for the PDE.
- **Part (c)** involved the weak maximum principle together with convergence arguments from functional analysis. The maximum-principle component was handled well by all students, while the convergence arguments were done well by most. The final part was a variation on a theorem proved in the course and required a detailed understanding of the original proof, together with the correct use of Sobolev embeddings and Hölder's inequality. Approximately half of the students answered this very well.
- **Part (d)** was a variation on an example discussed in lectures. About half of the students identified the required modifications to make the argument work, while others repeated the lecture proof without adapting it appropriately.
- **Part (e)** was answered well by approximately half of the students.

This was the most popular question and was attempted by all eight students. Three solutions were of first-class standard (one of which was almost perfect), two were of distinction standard, two were of intermediate standard, and one was just above the level of sufficiency.

Question 3. This question concerned monotone operators and quasi-linear elliptic PDEs. As with Question 2, it required a good command of prerequisite material, including functional analysis and Sobolev embeddings.

- **Part (a)** was largely bookwork with a small twist arising from the source term. It was answered perfectly, or almost perfectly, by most students. A few students failed to recognise the issue created by the source term, which required an integration-by-parts argument to establish that the expression was well defined.
- **Part (b)** was standard bookwork and was answered well by most students.
- **Part (c)** consisted of two parts. Part (i) was bookwork and was answered perfectly by all students. Part (ii) was more demanding, requiring the use of part (i) in order to exploit weak convergence fully. Only one student produced a complete solution, although another script made substantial progress.

The question was chosen by four students. Two solutions were of first-class standard (one of them almost perfect), and two were of distinction standard.

C4.9: Optimal Transport & Partial Differential Equations

Question 1: Parts (a) and (b) were straightforward and were in general answered quite well. Some candidates found part (c) more challenging. Part (d) was mostly well done too. Part (e) was the most complicated question for students this year but partial credit was taken by the students that attempted it.

Question 2: This was probably the one that some students found more difficulty to answer. Parts (a) and (c) were reasonably straightforward bookwork. Most of the students struggle to argue very well in part (b), (d) and (e) that have partial new rider parts.

Question 3: Parts (a) and (b) were generally well answered, although some students found difficulties in writing the good definition of weak solutions for the PDE. Part (c) was not answered fully by some of the candidates forgetting some parts to check. Part (d) was mostly answered well. 1Summary: This year's exam seems to have worked quite well to distinguish between the excellent and the very good students in the course. Overall, I am quite happy with the spread of marks, showing the high level of achievement of part of the cohort. The spread of knowledge and work on the material over the cohort seems to be consistent with previous years. All questions seemed to have been equally good for the students that is why my scaling raw marks values have been accordingly adapted with respect to previous years.

C5.4: Networks

C5.5: Perturbation Methods

Question 1 was a straightforward application of the method of stationary phase, and the many candidates were able to obtain the expression given in the question. However, the majority lost marks for not carefully justifying the approximations made, as done in examples in the lecture notes.

Question 2(a) was a straightforward application of the WKB approximation, with the ansatz given. The majority of marks lost here were for algebraic errors in deriving the expressions for $A_0(x)$ and $A_1(x)$. In part (b), many candidates did not see that the polynomial equation should have six roots, and so lost marks for not deriving expressions all of them – this was most easily done by writing the different roots in polar form.

Question 3 was a standard example of the method of multiple scales, with the slow timescale given in both parts of the question. Candidates struggled with correctly applying the initial conditions in (a), and in part (b) in deriving the expression for the phase difference.

C5.6: Applied Complex Variables

Question 1. The sketches of the potential and hodograph planes in part (a) were well constructed on the whole, though many candidates carelessly lost marks for not specifying the locations of the images of all of the points A , B , B' , C , D and A' . A few attempts also failed to preserve the correct ordering of the boundary points in the hodograph plane. The conformal mapping in part (b) was also well done on the whole, with nearly all candidates applying the Riemann Mapping Theorem correctly to determine the scaling factor M in terms of q . There were, however, a number of minor algebraic slips in manipulating the

fourth powers in the hodograph map.

In part (c) the differential equation for $z(\theta)$ was derived correctly by the majority of candidates. The tail of the question proved more challenging. While a significant minority stated the correct boundary conditions for the free surface, only a handful spotted the substitution required to derive the stated integral relation between a and q . This was a good discriminator at the top end, but with hindsight the final change of variables was perhaps a little too hidden.

Question 2. The bookwork in part (a)(i) on the Plemelj formulae was well done on the whole. Many candidates nevertheless carelessly dropped marks for not defining the orientation of the contour, the principal value integral, or the meaning of the limiting values from the two sides of the contour. There were also some rather sloppy arguments concerning the limiting process. The majority of candidates applied Cauchy's theorem correctly to derive the corollary in part (a)(ii).

The singular integral equation in part (b) was solved efficiently by nearly all candidates, most of whom introduced the auxiliary function and used the jump relation correctly. The equation in part (c) presented more of a challenge. A significant minority spotted how to use parts (a)(ii) and (b) to derive the first identity, but very few then substituted again for f in order to determine the explicit solution. The final step was algebraically short, but required a clear understanding of how the holomorphic terms should be treated inside the principal value integral.

Question 3. The bookwork in part (a) was very well done on the whole, with the majority of candidates scoring full or near to full marks. Most candidates correctly identified the branches of the square roots and the half-planes of analyticity of the Fourier transforms, though some lost marks for imprecise statements of where the Wiener–Hopf equation holds. The derivation of the Wiener–Hopf equation itself was also generally well done.

The majority of candidates produced excellent solutions to part (b), deriving the stated expression for $\tilde{f}_+(k)$ and writing down an appropriate inversion integral. A significant minority, however, made erroneous sum decompositions or chose inconsistent branches when defining $(-1 - i\epsilon)^{1/2}$. The inversion in part (c) proved an effective discriminator. Only a minority of candidates performed the contour deformation efficiently and accurately, keeping track of the branch cut contribution in the limit $\epsilon \rightarrow 0^+$. There were several good partial solutions, but many attempts either missed the contribution from the cut or were unable to justify why the remaining parts of the deformed contour could be neglected.

C5.7: Topics in Fluid Mechanics

The examination paper generated a broad spread of marks, and thus differentiated among the candidates, though the paper was found to be harder than expected and hence scaling has been recommended.

Question 1 This was exceptionally popular. Most candidates made solid progress through parts (a) and (b), though some reproduced related bookwork in part (a) rather than focusing closely on the question at the outset, leading to inefficiency that possibly had impact later. The similarity solutions in part (c), as explored in the porous media section of the course, were applied here for thin films, but this proved more difficult than expected. Nonetheless, a number of candidates made good progress. The very final part of the question, with

limited marks, was intended to be very difficult though no candidates made progress at this point.

Question 2 This was also extremely popular and most candidates made good progress in the earlier stages. However, recognising that curvature in the Laplace-Young equation is a physical quantity and thus takes the same value at a common physical point regardless of the coordinate system used to represent the free surface prevented many candidates, though far from all, from making significant progress in the final stages.

Question 3 The vast majority of candidates did Questions 1 and 2. Question 3 had very few attempts and hence the comments are based on a small sample. It combined porous-media theory with the Stokes-flow material from the final part of the course to determine the permeability of a porous medium. The bookwork on porous media was generally attempted well, but once the question moved on to the follow-on Stokes-flow part, most attempts began stalling, with time pressure typically evident at this point.

C5.11: Mathematical Geoscience

Question 1 - This question was generally done quite well. In part (a) it was intended that candidates explain that the steady state is stable, (not just that there is a steady state), which most did but a few didn't. A surprisingly common confusion in (b) was to say that $[\text{CO}_2]$ was a concentration of CO_2 in the atmosphere rather than the ocean. The algebraic manipulations in (c) were fine. In (d), many candidates got the shape of the nullclines correct and successfully argued that the equilibrium is stable when it exists, and many were able to argue why the trajectories must have $C \rightarrow A$ and $p \rightarrow \infty$ when $E > E_c$, but only one or two successfully explained why p would end up growing linearly in time.

Question 2 - This question proved to be quite challenging and in particular many candidates got very bogged down in poorly-organised algebra. The non-dimensionalisation in part (a) was intended to be straightforward - it is straight from the lectures - but most people made a hash of it and many appeared to give up. In part (b), it would have helped most candidates to clearly write out the linearised system of equations before attempting to seek solutions; the presentation of these solutions was generally very poor. More candidates had success with part (c) and a pleasing number had the right structure to the characteristic diagram. In many cases the algebra was again made much harder than it needed to be by only half employing the non-dimensionalisation and therefore working with unnecessary Q s and w s in the solutions. No-one gave a convincing answer to (c)(iii).

Question 3 - Part (a) was generally found to be straightforward. There were good answers to (b)(i), although the explanations for why ω would be large were often erroneous. A common mistake in part (b) was to use the recipe for finding the length from part (a), which assumed a steady state, and which gives much to wildly varying lengths of the glacier with the seasonally varying a . The first part of (c) was done quite well with many candidates finding the correct time for the glacier to thin. For (c)(ii), there were a wide range of answers, some of which were correct (some people seemed to use their intuition to guess that Q should increase on the long timescale due to climate warming; the point of the question in some sense was to show that this is not the case - the reduction in length of the glacier more than compensates for the larger local melt rate).

C5.12: Mathematical Physiology

Overall, the difficulty of the exam was appropriate. The earlier bookwork sections were well attempted, while the final parts of the questions were more challenging and separated the candidates well.

Question 1

This question was attempted by all but one candidate. Among those who attempted it, this question achieved the second-highest average mark.

In **part (a)(i)**, around half of the candidates did not spot that $(b/(a-1), b/(a-1))$ was an unphysical solution. As a consequence, those candidates did unnecessary additional work calculating the stability of this solution.

In **part (a)(ii)**, candidates struggled significantly with sketching the phase planes. A large proportion of candidates did not write down the equations for the nullclines, which made this part of the question even more challenging. All candidates attempted to illustrate the excitable trajectory, but around half did not do so correctly.

Part (b)(iii) appropriately separated the high-achieving candidates, although the majority made a good attempt at this part.

Question 2

This question was attempted by all but one candidate.

Parts (a) and (b) were well attempted by all candidates.

Part (c) was more challenging.

In **part (c)(i)**, only a small proportion of candidates drew curves resembling the correct shapes. The examiner was therefore lenient when marking this part. Many candidates incorrectly drew shapes similar to curves seen in problems studied in the lectures. This in turn meant that they were unable to draw the appropriate trajectories near the fixed points.

In **part (c)(ii)**, some candidates forgot that m_∞ was a function of v when differentiating.

The majority of candidates found **part (c)(iii)** difficult, and this acted as a good discriminator between candidate abilities.

Question 3

This question was attempted by only three candidates. Nevertheless, the candidates performed well. Among those who attempted it, this question achieved the highest average mark. All candidates were able to answer **parts (a)–(f)** well. **Part (g)** was challenging, but good attempts were made.

C6.1: Numerical Linear Algebra

The three questions were roughly equally popular and each was attempted by similar number of candidates.

Q1(a) (i), (ii) mostly fine. Some answered (ii) without using the SVD, which was marked down by 1. (iii) is bookwork, but seemed surprisingly difficult. (iv) is also bookwork and most serious attempts were fine.

Q1(b) (i) A number of attempts used Marchenko-Pastur with incorrect sizes. (ii) There was a typo in the size of Y in (ii) (stated as $s \times m$ rather than the correct $m \times s$); the vast majority of attempts seemed unaffected, but adjustments were made where this visibly had an impact. (iii) This is actually not a difficult problem once one observes that the left-hand side is a sketch-and-solve solution of the problem in the right-hand side.

Q2 (a)(i) bookwork but several candidates struggled to find the Householder vector. (ii) many attempted to solve an optimisation problem; it is a simple geometric (or triangle inequality) argument together with (i). (iii) should also be straightforward, but some attempts made it very complicated. (iv) In lecture notes but appeared to be challenging. Some attempts were circular.

(b) (i) Mostly fine. (ii) To minimise the quadratic form, convexity needs to be mentioned to claim the stationary point is the minimiser. (iii) Many attempts were imprecise. (iv) Ditto.

Q3 (a) (i) A direct application of Courant-Fischer, but attempts without using it seemed to struggle. (ii) Mostly fine, some used lengthy calculations. (iii) Not many candidates got the eigenvalues and their multiplicities right. (iv) A large number of candidates claimed the norm of the projector was 1, which is incorrect.

(b) (i) Fine. (ii) Several imprecise attempts, e.g. claiming $\|SQ\|_2 = \|S\|_2$; this is wrong as Q is tall orthonormal (while $\|QA\|_2 = \|A\|_2$ is correct). (iii) most serious attempts were successful. (iv) was intended to be somewhat tricky, but there were several correct solutions.

C6.2: Continuous Optimisation

The students tackled some parts of questions confidently but I believe they also found some parts challenging. For example, in Question 1, a few students wrote down quasi-Newton methods instead of modified Newton (some points were allocated for the former but not full marks). Students also found it difficult to verify the conditions of the theorem they stated in part (a)(iii) in the case of modified Newton. The calculations in part (b) also proved somewhat challenging, possibly due to time pressure. Question 2 overall was not done as well as Questions 1 and 3. This is due to the novel angle here, to have a question that addresses regularization instead of trust region in the subproblem. The solutions to Question 3 were better than to the other questions, but the opening bookwork parts did not materialise for all as I was expecting. Overall, some top answers and performance.

C6.4: Finite Element Methods for Partial Differential Equations

Question 1 was along the lines of previous years, asking about a previously unseen finite element and a PDE that it is suitable for approximating. (a) Candidates generally had the right idea (one must enforce tangential continuity), but many candidates did not demonstrate why it is necessary by means of integration by parts and cancelling the boundary term. This was somewhat surprising, since the question was asked on an early problem sheet. (b) Candidates generally dealt with (b)(i) well, expanding the basis with coefficients and showing that the degrees of freedom being zero forced the coefficients to be zero. Parts (b)(ii) and (b)(iii) were generally answered well. (c) Some candidates struggled to derive the correct variational formulation in (c)(i); they did not use the Leibniz rule or scalar triple product formulae recalled in the question. Parts (c)(ii) and (c)(iii) were generally answered well.

Question 2 asked about the weak enforcement of Dirichlet boundary conditions using Nitsche's method. (a) was obvious and well-answered. In (b), the main failure mode was to forget to write $u = w + g$ where $w \in H_0^1(\Omega)$; candidates invoked the Riesz representation theorem without accounting for the fact that $H_g^1(\Omega)$ is not a Hilbert space. Some candidates offered long and elaborate arguments for (b)(ii), but simply observing that it follows from conformity sufficed. (c)(i) This was generally answered well, but some candidates struggled to cancel the terms with the test function on the boundary or to substitute u for g in the remaining surface integral. For (c)(ii), many failed to integrate by parts correctly, or to observe that doing so cancelled the required surface integral. (d)(i) was generally answered well, with some candidates running out of steam in the calculations, and failing to choose an ϵ so that both terms in the lower bound are positive. Similarly, (d)(ii) was generally answered well, with candidates identifying that the question required proving the boundedness of a_h and F_h ; the main failure mode was a lack of endurance to carry out the calculations required.

Question 3 considered error estimates for nonconforming approximations. (a) was generally answered well. (b)(i) was also generally answered well, with almost everyone correctly employing the triangle inequality and bounding the second term with the consistency error. (b)(ii) and (b)(iii) were also generally answered well, with candidates correctly splitting the consistency error and identifying that the error estimate simplified with Galerkin orthogonality. (c)(i) was generally answered well, with candidates successfully employing the estimates provided in the question to derive a coercivity bound. (c)(ii) was harder, with some candidates failing to bound the consistency error, usually by failing to realise that two of the terms evaluated to the right-hand side linear functional and thereby cancelled.

C6.5: Theories of Deep Learning

C7.4: Introduction to Quantum Information

Question 1: This question seemed to be relatively easy for those who attempted it. Students who completed all five sections usually struggled only with the details of the T-count in the Matsumoto–Amano form. Otherwise, it was interesting, and a little puzzling, to observe that a number of students switched to explicit matrices when proving simple relations involving Pauli matrices. This showed some lack of confidence with algebraic manipulations,

but as long as the derivations were correct, even if too pedestrian for this level, they received full marks. In part (a), students had little difficulty interpreting the Pauli gates as rotations. The interpretation of the Hadamard gate was also generally not problematic, although some students simply gave the correct answer without attempting to justify it. Parts (c) and (d) were usually handled well. In part (e), most students figured out how to use the Clifford push-through lemma to arrive at the Matsumoto–Amano normal form, but many struggled to give a good explanation of the T-count. Overall, this appeared to be a relatively easy question, which came as a pleasant surprise, since this was a new topic introduced in this year's lectures.

Question 2: This question was generally well-attempted, with many errors seeming to stem from misunderstanding of what was being asked, likely due to time pressures. In parts (a), (b) and (c) essentially all students got full marks on these bookwork questions, with the main source of dropped marks being students forgetting to prove parts of question (c), most usually the fact that the operators are indeed projectors and are indeed orthogonal. In (d) Most students got the first two marks for stepping through the circuit and obtaining the correct measured states, but lost a mark for incorrect algebraic manipulations (often forgetting that $V^2 = 1$ in obtaining the probabilities. In part (e) those students who understood the question usually got full marks, and often by creative diagrammatic methods (probability trees, outcome tables, flow charts). Almost all students who didn't get any marks misunderstood the described protocol. In (f) many students got tripped up with double negatives and confusingly worded proofs (e.g. "if the measurement outcome is not 0 then Alice can not conclude that the states are not identical"), but demonstrated understanding of the main argument. However, this was the start of where some students struggled and gave up with the rest of question. In part (g) most students appealed to a fact from lectures / problem sessions (namely that the trace of the swap operator applied to a tensor product is the trace of the (matrix) product), making this question surprisingly well answered. Those who did not use this fact generally still succeeded with a by-hand calculation in terms of matrix entries. In (h) many students repeated the essential argument from (f), thus answering incorrectly. However, those that answered correctly often gave an argument involving the purity of a mixed state rather than a brute-force calculation, showing good understanding. Finally in (i) those students who wrote more than a sentence or two for this question tended to have the correct idea (estimating P_0 and thus the trace), but didn't quite complete the argument in terms of algebraic constraints on the eigenvalues.

Question 3. The question was generally well attempted. Most candidates answered part (a) correctly, with only a few exceptions. Some claimed that S_i must act on an even number of D_i , rather than recognising that it must overlap with each S_j of the opposite type on an even number of D_i . In part (b), most students realised that single-qubit errors can be detected. Many also realised that some two-qubit errors cannot be detected, but not all pointed out that, in this case, all such undetectable errors are stabilisers. Even though part (e) already mentioned the possibility of Y errors, in part (f) a small fraction of students still considered the case in which bit-flip and phase-flip errors occur entirely independently, thereby deducing that Y errors occur with probability p^2 . This interpretation was accepted as a valid answer if it was followed by the correct argument about the error probabilities. Several students dismissed Y_1 in this scenario without giving any explanation. In part (g), many students forgot to mention that both operators cannot be in the stabiliser group if they are intended to be logical X and logical Z . Answers to the effect that the two operators anti-commute were accepted, since this is possible only for non-identity logical operators.

When attempting to address the geometric property, some students said only that the operators intersect stabilisers an even number of times, failing to recognise that this is an algebraic property rather than a geometric one. Finally, in part (h), marks were lost largely through a lack of care in reading the question. Several students failed to give the number of physical qubits required, giving only the distance of the code. In addition, some missed that an argument was needed to justify $k = 1$, for example by explicitly counting the number of independent stabiliser checks.

C7.5: General Relativity I

Question 1

1 (a) (i) tripped up more students than expected. In deriving the Euler Lagrange equations for x when taking a derivative with respect to λ of Φ they only picked up terms with x derivatives from the chain rule and ignored the y derivative terms. Conversely when working out the y EOM they did the converse. This affected their computation of the Christoffel symbols but propagated errors were taken into account. There was some difficulty in computing the Ricci tensor but typically it was done well. For those using the incorrect Christoffel symbols it was marked based on their previous answers not the actual answer so many did not lose any marks here despite having an incorrect result. The question hinted that there was a single equation but many derived 3 distinct equations, this should have been something students flagged and realised they had made mistakes previously. For 1 (a) (iv) this could be done without explicit computation and it needed to vanish.

For 1 (b) (i) this was usually done well but one needs to specify both ϕ and ρ (or say ρ is constant). Just giving $\phi(\lambda)$ is insufficient. 1 (b) (ii) was usually done well, noting that the geodesic equation could not be satisfied. 1 (b) (iii) was not done well typically, some students left A as an operator equation with derivatives inside but this does not make sense when acting on the constants. For those computing the parallel transport explicitly writing it as a matrix was usually done correctly.

Question 2

This probably included the most fiddly question on the exam 2 (1)(iii). 2 (a) (i) and 2 (a) (ii) were bookwork and most got full marks. For 2 (a) (ii) some did not know where to begin and struggled. A common mistake was expanding out the covariant derivatives incorrectly, whilst others got stuck almost immediately. Students either got very few marks on this part of the question or most of the marks with little in between.

For 2 (b) (i) this was almost always done correctly. For 2 (b) (ii) and 2 (b) (iii) you must state that it is valid for all points and that the equations are tensorial so it is true in any coordinate system and anywhere on the manifold and therefore an identity. Many students did not do this and subsequently lost marks. Otherwise the manipulations for 2 (b) (ii) was typically done correctly, with 2 (b) (iii) causing a few more problems when the students did not want to expand out the Christoffel symbols in terms of derivatives of the metric which lead to them going round in circles trying to use the other symmetries (which are not sufficient to prove this).

Question 3

There was a small trick to see if the students understood what they were doing by slightly modifying the metric on the sphere. Most students understood the difference and proceeded in the correct way but those who had this question memorised rather than understanding it, got tripped up. 1 (a) (i)-(iii) were well done (minus the $\theta = 0$ vs $\theta = \pi/2$) and standard computations they have done before. For most 3 (a) (iv) was not a problem, but some did not realise that it requires the potential to be at a critical point not just setting $\dot{r} = 0$. For 3 (a) (v) the results were 50-50, often with no reasoning. A quick plot of the potential computed in 1 (a) (iii) shows that elliptic orbits are not possible.

For 3 (b) (i) a few struggled with finding the equation that at r_0 $\dot{r} = 0$. 3 (b) (ii) was then usually fine. A typical wrong answer for 3 (b) (iii) just integrated straight from r_A to r_B which is not the correct answer. One needs the negative sign for r_A to r_0 and the positive sign from r_0 to r_B . Taking the modulus sign outside of the full integral is also not sufficient. Many realised that this was just flat space and so the answer should just be the length between r_A and r_B but some did not and tried to interpret their incorrect answer.

C7.6: General Relativity II

Question 1

Most students attempting this scored well on part (a) which was largely bookwork and seen material. Almost every attempt correctly answered 1 a (i), (ii) and (iii). A few had some issues with 1 (a) (iv) despite having been seen in lectures.

For 1 (b) (i) most gave the correct gauge, though some missed 1 part of the TT gauge condition. On the whole only about 50% attempting 1 (b) (ii) wrote down the correct equation for to show the effect of a GW acting on a particle at rest.

1 (c) was the new material and was generally not done well. Most (incorrectly) guessed that the answer was N is even without doing any computations so it was not possible to give any marks. A little working out would have given these students some marks. For the most part 1 (c) (ii) was done correctly except students forgot to evaluate it at the retarded time and hence lost a mark.

Question 2

This was the question with the largest average. Most got full marks or near to full marks on 2 (a), with quite a few students noticing that the metric is Reissner–Nordstrom with a particular choice for M and Q . A few students forgot the definition of the surface gravity which cost them some marks. 1 (a) (iv) was meant to be a nice check that all the results previously were consistent but some students did not realise this.

Answers to 1 (b) typically got 4 marks as it was book work. 1 (c) typically either got 4 marks or 0 marks with the latter students stuck where to begin.

Question 3

The most popular question. Typically students got between 8 or 10 marks on 3 (a). Common pitfalls were forgetting to put a $e^{-2\Omega}$ in the inverse metric leading to wrong terms. This should have been spotted from 3 (a) (ii) where despite having these spurious factors the students still recombined this into a covariant derivative incorrectly. For 3 (a) (iii) some students ignored everything they wrote previously (and the first part of the question) and computed the geodesic equations again. 3 (a) (iv) was done well.

For 3 (b) students typically got 5 marks comfortably, though there were some students who ignored the hint for (b) (i) and then could not integrate. Parts 3 (b) (iii) and 3 (b) (iv) were typically poorly done. Students could not show that the change of coordinates made the metric smooth at $r = r_3$ which could then be continued to $r = 0$. Some students instinctively put that the r coordinate can now go to $-\infty$ despite their calculations indicating otherwise. For the Penrose diagram many students started on the correct track but then did not work out the coordinate ranges and seemingly guessed an incorrect solution. Those that worked out the coordinate ranges saw quickly that the diagram is just the one drawn for the maximal extension of Schwarzschild.

C7.7: Random Matrix Theory

Feedback on Q1

This question was about global eigenvalue statistics of Wigner matrices, and was attempted by almost all students. Part (a) was bookwork and was generally well answered; although the Dyck paths themselves required careful definition. Part (b) required an understanding of several steps in the proof of the Wigner semicircle law. There were many good answers, although care was needed to prove the limit of $\mathbb{E}[s_{2k}]$ was given by $|D_k|$ with no other factor. Some students assumed unnecessarily that all odd moments vanish (which happens in the Gaussian case). There was a typo in part (c), the even moments are given by $|D_{k/2}|$. While this is clear from the semicircle law, the mark scheme was amended to avoid penalizing any students who may have been affected by this. In part (c) (ii) the full expectation was required, not only the leading order term. There were several excellent answers to the later parts of this question.

Feedback on Q2

This question analyses the probability of positive definiteness in the GUE and the comparable question for a Poisson process. This question had relatively few attempts. Part (a) is the proof of Andreief's identity which appeared on a problem sheet. Different approaches to the proof are possible, and this was broadly well done. Part (b) applies this identity to reach a given formula. There was a minor typo (m in place of n) in the given GUE eigenvalue density that is easily identified and seemed to be inconsequential. This was again broadly well done, to make progress you need to insert the Vandermonde determinant, and take care with indices. For part (c) most students gave a correct characterisation of positive definiteness, but even with a correct set up struggled to make progress on the exact calculations. In part (d) there were similar calculation issues with the Poisson process; very few

answers mentioned eigenvalue repulsion as a difference between GUE and Poisson, which could have been discussed even without the exact formulas.

Feedback on Q3

This question was about local eigenvalue statistics in the CUE and was very popular. Early material on the projection kernel was broadly well answered, with the occasional error when relying on memory rather than making a short analysis from scratch. The proof of Gaudin's lemma was often well answered, although there were some notational issues. In particular, it is important to separate the dimension of the matrix from the label on the projection kernel. The final part was often well answered. Clarity was needed to distinguish eigenvalues from eigenangles, and to motivate the rescaling for the sine kernel. Issues arose in evaluating the integral, which can be done directly with care. It is slightly easier to use the definition of S_n as a sum rather than as a ratio of sines here, although the latter also works; changing variables was usually unhelpful.

C8.1: Stochastic Differential Equations

Question 1 (b.ii) needed either a careful use of OST with a finite stopping time (not τ as the point is to show that it is finite). Some students invoked basic properties of BM, which was considered fine. Only very few student tried really to justify that the probability $\mathbb{Q}$ was a conditional probability in (c.ii). Few that tried (e) paid enough attention to pass to the limit as $L \rightarrow \infty$.

Question 2 (a) was done correctly by most who tried it. Many however just tried to prove equality in law for marginals in (b.i). Somebody tried to use Ito formula to find an SDE for Y which is tricky as there is a change of time involved, but one or two students managed to argue convincingly. Few used the DDS theorem. Very few students properly solved (b.ii) which was just a careful computation of almost sure limit to $\pm\infty$. (c.ii) was justified by only around half of the students who attempted it and the proper limit even by few. (d.iv) was done wrong by the majority, or just sketched vaguely. (e) was attempted by few and done correctly only by a couple of students.

Question 3 (a) was done correctly by most. In (b.i) Novikov criterion was correctly invoked by the majority who tried it, but the correct way to bound the exponential in (b.ii) was not noticed, in particular the fact that the p -th power modify the exponential martingale even if a clue was given in the previous part. (c) some of the student missed the monotonicity property in (c.i) and others didn't argued carefully enough for the limit in (c.iii). (d) was attempted by very few students, some of them arguing essentially correctly while others making mistake in the application of the chain rule.

C8.2: Stochastic Analysis and PDEs

Question 2 and Question 3 were the most popular although a fair number of candidates attempted Question 3.

Question 1: A common mistake in (a) was to ignore the domain of the generator. Also few candidates justified Optimal Stopping. For (b) most candidates had good attempts at the

change of variables but often failed to give justification (exploiting that C is increasing and change of filtration).

Question 2: Overall good attempts with many candidates making good progress on all three parts.

Question 3: A surprising number of candidates made sign errors for the generator. Overall, good attempts, but few made progress on the second part of (c)

C8.3: Combinatorics

Question 1 was attempted by the fewest candidates, but there were some good solutions. Many did not follow the hint in (c)(i), which reduces the question to the (simpler) one-dimensional case.

Question 2 was mostly very well done, with almost all candidates giving correct solutions to the first three parts. Most candidates found the last part tricky, with only a few finding the simple example (all k -sets from a $(2k-1)$ -set).

Question 3 was also popular. Most candidates (correctly) used part (a) to find upper bounds on the families in parts (b) and (c), but some did not try to give matching constructions for a lower bound.

C8.4: Probabilistic Combinatorics

Question 1 Almost all students attempted this question and parts (a) and (b) were generally done correctly. Part (c) was slightly harder, but again, most students were able to find the right strategy for solving it, and those that did generally solved it correctly. Part (d) was the part that caused most difficulty. One common issue is that students proved that a pair of events A_i and A_j with $|i - j| \geq 2$ are independent (as indicated by the hint), but did not realise that one actually needs the stronger condition that A_i is independent of the family of events A_j with $|i - j| \geq 2$, so that the collection of A_i with i even, say, is independent. The other main issue was failing to spot that if $X \geq \frac{n-1}{2} + t$ then one of the even or odd counts must be at least $t/2$ more than its mean.

Question 2 Very few students attempted this question. Those that did generally did well on parts (a)-(c), but did not know how to tackle (d). Part (d) was actually just a 1st moment calculation on the number of proper k -colourings, but students generally tried more complicated approaches, such as estimating the maximum size of an independent set, and unfortunately these approaches went nowhere.

Question 3 Almost all students attempted this question. Again, the bookwork parts (a) and (b) were generally done very well. Part (c) was also usually done well, however some students failed to find the correct approach to part (c), which was to show the probability that a fixed vertex v is in no K_4 is extremely small. There were attempts that started by asking for the probability that a fixed K_4 contains a random vertex, which does not really make much sense. For those that followed the correct approach, a common mistake was to give an upper bound only on the mean number μ of K_4 s that v is a part of. One really needs a lower bound for this as one wants $\exp(-\mu + \Delta/2)$ to be small.

Summary Scores were on average fairly high, with a reasonable spread. Bookwork was

generally done extremely well, and when students fell down in the last parts of the questions, it was usually as a result of failing to spot a correct approach to the problem.

C8.7: Optimal Control

Question 1 was taken by the majority of candidates, and was overall done fairly well. Most candidates who attempted the question gave a correct statement of Pontryagin's principle, and identified the appropriate state variable, however some did not translate this into the correct two-dimensional dynamics in part (b). The solution of Pontryagin's equations was variable (and could be done either using original problem, or the extended state variable), however some candidates did not identify the correct terminal value for the costate variable. No students completed part (e) fully, which required noticing that, in order for the terminal cost (not including the running cost) to be zero, the terminal state is zero, and hence the costate variable must be identically zero. This allows you to simply write down the optimal control, and hence observe that the initial state must be $x_0 = 0$.

Question 2 was done by approximately a third of candidates. The first parts were done well, however some demonstrations of the contraction property of $\mathcal{R}$ in part (b) were insufficiently clear. In part *ci* it was important to explain why convergence will generally not occur (not simply that the Robbins–Munro conditions fail), and to explain that the convergence is almost sure given the initial sample. The final step required some manipulation of the error terms, and was not clearly done. *In the specification of part (c), there was a minor typo, where the index of Q in the iteration was n rather than t . This did not cause any apparent confusion to any candidate.*

Question 3 was taken by the majority of candidates, and was well done overall. Most candidates correctly identified the HJB equation and used a first order condition to obtain the candidate optimal control. The manipulation of the ansatz was generally well done in parts (c) and (d). Part (e) had a variety of answers, with some candidates simply saying that the ansatz would not have worked (which is an insufficient answer), but others correctly identified that the infimum over controls would involve taking $U \rightarrow -\infty$ in which case $X \rightarrow \infty$, resulting in a finite value (but an ill posed problem for the dynamics).

Statistics Units

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

- SC1 - Stochastic Models in Mathematical Genetics
- SC2 - Probability and Statistics for Network Analysis
- SC4 - Advanced Topics in Statistical Machine Learning
- SC5 - Advanced Simulation Methods
- SC6 - Graphical Models
- SC7 - Bayes Methods
- SC9 - Interacting Particle Systems
- SC10 - Algorithmic Foundations of Learning
- SC11 - Climate Statistics

Computer Science

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

F. Comments on performance of identifiable individuals

1. Prizes

The following prizes were awarded:

- Gibbs Prize. Rebekah Glaze, Keble College
- Gibbs Prize. Zhenyu Yang, Corpus Christi College
- Gibbs Dissertation Prize. Lila Spencer, The Queen's College
- Junior Mathematics Prize. Yicheng Xia, St Anne's College
- IMA Prize. Kira Patel, Mansfield College

G. Names of members of the Board of Examiners

- **Examiners:**

Prof. Emmanuel Breuillard (Chair)
Prof. Jose Carrillo de la Plata
Prof. Massimiliano Gubinelli Prof. Alan Lauder
Prof. Philip Maini
Prof. Rosemary Dyson (External)
Prof. Roger Moser (External)

- **Assessors**

Prof. Konstantin Ardakov	Prof. Jon Chapman
Prof. Hülya Argüz	Prof. Gui-Qiang Chen
Dr. Paul Azzopardi	Prof. Dan Ciubotaru
Prof. Ruth Baker	Dr. Goylette Chami
Prof. Paul Balister	Prof. Sam Cohen
Dr. Paul Bastide	Dr. Chris Couzens
Dr. Martin Bays	Prof. Andrew Dancer
Dr. Philip Beeley	Prof. Paul Dellar
Prof. Dmitry Belayev	Prof. Jamshid Derakhshan
Dr. Corentin Bodart	Dr. Karel Devriendt
Prof. Pierrick Bousseau	Prof. Chris Douglas
Dr. Lukas Brantner	Prof. Artur Ekert
Prof. Michael Bronstein	Prof. Radek Erban
Prof. Maria Bruna	Dr. Carles Falco i Gandia
Dr. Rhuardi Burke	Prof. Patrick Farrell
Prof. Helen Byrne	Dr. Simon Felten
Dr. Zhenyu Cai	Dr. Paz Fink Shustin
Prof. Coralia Cartis	Prof. Eamonn Gaffney

Prof. Mike Giles
Dr. Kathryn Gillow
Prof. Alain Goriely
Dr. Andrew Graham
Prof. Ben Green
Prof. Ian Griffiths
Prof. Ben Hambly
Prof. André Henriques
Prof. Ian Hewitt
Dr. Christopher Hollings
Dr. Dan Hill
Prof. Peter Howell
Prof. Kaibo Hu
Dr. Melissa Iacovidou
Dr. Nick Jones
Prof. Dominic Joyce
Prof. Andras Juhasz
Prof. Mehrdad Kalantar
Prof. Dawid Kielak
Prof. Robin Knight
Dr. Dowan Koo
Dr. Noah Kravitz
Prof. Yakov Kremnitzer
Prof. Jan Kristensen
Prof. Renaud Lambiotte
Prof. Alan Lauder
Dr. Sun Kai Leung
Dr. Torkel Loman
Dr. Ilya Losev
Prof. Jason Lotay
Dr. Mattia Magnabosco
Prof. David Marshall
Prof. Lionel Mason

Dr. Christiana Mavroyiakoumou
Prof. James Maynard
Prof. Kevin McGerty
Prof. Andrea Mondino
Prof. Derek Moulton
Prof. Andreas Muench
Dr. Devarshi Mukherjee
Dr. Alp Muyesser
Prof. Yuji Nakatsukasa
Prof. Vidit Nanda
Prof. James Newton
Prof. Nikolay Nikolov
Prof. Harald Oberhauser
Prof. James Oliver
Dr. Erik Panzer
Prof. Panos Papazoglou
Dr. Fedor Pavutnitskiy
Dr. Jennifer Pi
Prof. Zhongmin Qian
Prof. Oliver Riordan
Prof. Alexander Ritter
Prof. Damian Rossler
Prof. Melanie Rupflin
Prof. Alexander Scott
Dr. Apurva Seth
Dr. Jakub Skrzeczkowski
Prof. Rolf Suabedissen
Prof. Jared Tanner
Robin Thompson
Prof. Qian Wang
Prof. Stuart White
Dr. Hanneke Wiersema