IMO 2023 Report

Introduction

The 64th International Mathematical Olympiad was held in Chiba, Japan from the 7th to the 13th of July, 2023. Prior to this, a joint UK-Australia training camp was held in Fuchu, Japan from the 29th June to 6th July, meaning a fully in-person Pre-IMO camp and IMO for the first time in four years. Here is a taster of what we experienced in this eventful two-week period.

28/06/2023 – Departure from Heathrow

We meet up at Heathrow Terminal 3, with the exception of Hanks, who will be joining us at Haneda airport. In the time since the final selection camp at Oxford, the Year 13's have survived an onslaught of A-Levels and STEP exams. Yet for Will, the papers never stop coming, as he agonises over the IOL mocks he has to get done immediately after the IMO.

While waiting during check-in and at the gate, we find that it's Isaac and Will's first times on a long-haul flight, but with Ava having given us a lot of advice in combating the jet-lag, we feel sufficiently prepared. After brief mentions of the fake cricket Ashes, which is followed by Isaac, Dominic and Freddie, our conversations unconditionally converge to the problems on the IMO Shortlist 2022 sent to us a week prior, as well as the USA TSTST 2023 paper released just a few days ago. Comments include:

1. IMOSL/C4: Wow this is well-known; it was literally presented in the Hungary camp.
2. IMOSL/A7: Hmm maybe this shouldn't be A7...
3. IMOSL/A5: Why are the SL 5's this year so difficult? Sida has a really wacky solution.
4. IMOSL/G6: Isaac and Thomas attempt at applying moving points.
5. IMOSL/N8: What on Earth is that?!?
6. TSTST/5: What on Earth is that?!? – Alex

For dinner, we head to an Italian place, after Dominic notes that Wagamama may not be the most culturally appropriate choice of restaurant considering our flight destination. For some of us, we are missing the last few days of school, the Year 13 prom or a graduation trip. When our food arrives, Dominic and Freddie are reminded of the extremely cheesy

pizza they ate for lunch, in preparation for the lack of dairy in Japan. Also in preparation, we test each other's Japanese language skills, with Sida knowing a few basic phrases, and Isaac exactly 3: 'Hello', 'Thank you', and... 'Stop it'.

After an obligatory boarding selfie, we board the plane. As per Ava's recommendation, we all try to get some sleep (plus the lights were off the whole time so this hinders our problem-solving capability). There is slight turbulence partway, but overall a smooth 11 hour plane journey.

Figure 1: Boarding selfie - a necessary tradition

29/06/2023 – Arrival in Fuchu

As soon as we step off the plane, a massive wave of humidity hits us. Going through security was mostly smooth, though during baggage reclaim, a long wait meant we were hearing the same pre-recorded message about 30 times over, to the point where Freddie started memorising the English, and Sida the Japanese. Will's bag gets sniffed out by a security dog, and he explains that it was likely the residual scent of bananas though no bananas were actually present. (Will is a massive fan of bananas.)

After passing through customs we meet up with Hanks, Yuka, Noriko (Yuka's mum and our guide in Fuchu), as well as... Po-Shen Loh? It turns out he's here for a completely unrelated matter and will later go to the IMO. We board a taxi, and the journey is filled with discussions of Japanese breakfasts, Yuka's experience at MIT, and Hanks describing the WEOI problems to Isaac, with one problem a variation on graphical vectors.

When we arrive at the hotel, we head to our rooms (of course with a fancy multi-purpose toilet), and then to dinner. It turns out there is a procedure for the dinner buffet, including wearing disposable gloves to pick up a select few dishes. There is a wide selection of sashimi (sliced raw fish), tempura (fried foods), and jellies, and it's a great introduction to Japanese cuisine.

30/06/2023 – Fuchu Excursion

As we're discussing over breakfast whether to have the AC on or not whilst sleeping (the verdict is yes), we see the Australian team arrive. For our morning excursion (while the Australian team get sorted), we set out into the blistering heat brandished with our caps and umbrellas. Everywhere around us are vending machines upon vending machines. We eventually get to a shrine, where some of us decide to perform a ritual of washing out hands and faces before praying, while Sida and Hanks opt out. We follow a Japanese man in bowing into the shrine, but then Yuka realises this was the wrong direction to the park, so we immediately bow out of the shrine. We ask Yuka about the periodicity of earthquakes, to which she replies 'Quite common, maybe a small one every 2 weeks', which is perfect for those of us wanting to tick it off our bucket list.

Figure 2: Escaping from the downpour

We take a stroll in a local park, and in the pond we find a rock with a turtle proudly claiming it as territory. Due to a sudden large downpour, we stop for a bit, and the conversation transitions from Isaac noticing a variety in leg wear to Freddie being the only person to recall his blood type. After the raining stops, we find an old locomotive exhibit, with life-sized versions of steam trains and buses (though one was an actual bus). Dominic alerts Sida that he may wish to think about his handwriting, reminiscing about a very rushed C5 in TST's.

In our first game of Mao, Will brings out the now infamous 'incorrect card placement rule', with Hanks the first 'natural' and Sida, Thomas and Alex utterly confused. Nanako from Trinity Camp comes and greets us with some Japanese snacks, a pleasant surprise.

We have lunch at a Chinese place within the hotel lobby. Will is improving with his chopstick skills, and that prompts Thomas to give the story of how his family transitioned from metal utensils to chopsticks. Thomas and Hanks also seem to have found an infinite food glitch, whereby upon completion of a soup, you obtain another soup. Thomas tests the surpremum of this seemingly fruitful induction, but doesn't want to abuse the goodwill of the staff so stops after 3 cups. Hanks gives into peer pressure from Sida, and they both enjoy a second

cup of soup. We also experiment with adding various amounts of 'gum syrup' to our iced teas.

In the evening, Will introduces us to the card game of Sevens. It turns out that playing card games on an uneven bed in a small room proves to be relatively cumbersome.

01/07/2023 – F1

For a traditional Japanese start to the day, Noriko recommends us the 'natto', which is a fermented bean dish, and 'tamago gohan', raw egg mixed in rice. Freddie tries the latter and enjoys it, whereas there are mixed emotions regarding natto.

We all enter the exam room excited for our first of 5 training exams, and find that UNK and AUS tile the desks in a chessboard colouring. Of course, Will is prepared with his bananas, Sida with his Ferrero Rochers, and Isaac with his duck (plastic, not alive).

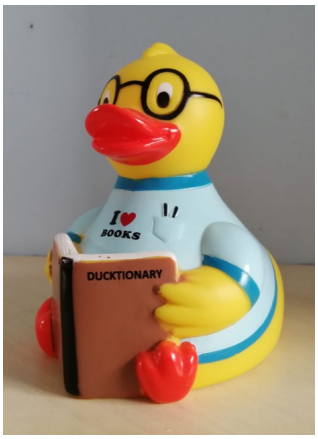


Figure 3: Isaac's signature duck.

And thus the exam begins.

1. P1: A bound construction combo involving sharing paintings. Most people have a circular construction though Sida and Will give a grid-based construction. Alex got baited by the grid.
2. P2: Another geometry problem starting 'Given that…'. There are interesting synthetic solutions, though Sida and Isaac find the 4-line harmonic bundle chase.
3. P3: IMOSL 2022/A6, a functional equation of a unique flavour and weird solution set. Thomas adopts a nice chains approach, and Alex something similar.

All of us (apart from Alex of course) forget to consider the degenerate case in P2, which was sneakily hinted by the phrase 'Find the locus of all points' in the problem statement. Chris from the Australian team manages to identify this in his trig-linearity-of-power-of-a-point bash… a rare W for bashing?

For lunch, we head to a food court, where Thomas and Will passionately discuss the ups and downs of the Star Wars franchise. Then we witness a father let his daughter get dangerously close to going down an up escalator, and collectively we agree this is much more dangerous than going up a down escalator. Thomas then proposes, via extremely rigorous moment and centre of mass calculations, infinite cartwheeling on an escalator. As we ponder this proposition, Ava finds a donut store selling the famous mochi donuts; they are definitely worth the hype.


Figure 4: Mochi donuts

After heading back, we bring some games to the exam room, where Hanks and Thomas begin a unique tradition of exhaling loudly when starting a game session. First, we discuss our prospective F3 paper. Naturally our shortlist is significantly smaller than the Australian's, with a geometry problem from Isaac, another from Alex, and a KoMaL NT from Sida, compared to the 8 geos on theirs. Eventually, we come to the conclusion that Alex's geometry is possibly a bit too hard (though this is likely influenced by Sida's overkill 16-claim solution), and settle for P1 from TST's, Isaac's geometry, and P9 from TST's.

Let the games begin. Will and Isaac proceed to demolish at Geistes, with Hanks developing a viable strategy of focusing exclusively on the red chair. Then the Australians join us for a lovely game of Mao, or as they put it, Dinosaur. We enforce both UK and AUS base rules, and Isaac introduces Will's rule to torture the Australians. Unusually, Sizhe manages to succeed 50% of the time.

Dinner is at a Western place in the reception of the hotel. We lament over different problem sub-topics, with existence combo and config geo universally disliked. Somehow this transitions to Alex and Thomas hating on Man City. The Australians also debunk the myth of living with dangerous animals, although Chris claims to have had an opossum infestation in his roof.

02/07/2023 – F2

Another day, another exam.

1. P1: IMOSL 2022/A2. Classic bound algebra.
2. P2: At first sight, quite an unsightly diophantine equation triple, but once you get into the meat of it, it turns out to be very clean.

3. P3: IMOSL 2022/C7. Huh?

After being bewildered by the answer of 3 for C7, we head to one of our main events: sword-fighting! Inside the dojo are walls of swords, and there we meet our sensei. She introduces the martial art of Tate, specifically designed for acting. We learn a bit of history about Tate, fighting etiquette and seppuku, and when asked what comes to mind from the word 'Samurai', unknowingly we produce some thoughtful and wholesome answers which surprise the sensei.

Then she begins to teach us how to grip a practise sword, the fighting stances, and finally a few sequences of moves. Once, one of the junior instructors forgets the moves and the sensei rushes them off to replace them. Not long after, we are immediately thrown into a real battlefield, just kidding that would've been immediately prohibited by UKMT safeguarding guidelines. But instead our skills were put to the test in a live action sequence, where each of us went up to defeat two approaching enemies. Highlights include Isaac becoming a man possessed, swinging as if the two opponents in front of him were supporters of 3-variable inequalities. Iris starts laughing whilst slashing her foes, giving a maniacal vibe to her otherwise kind expression.

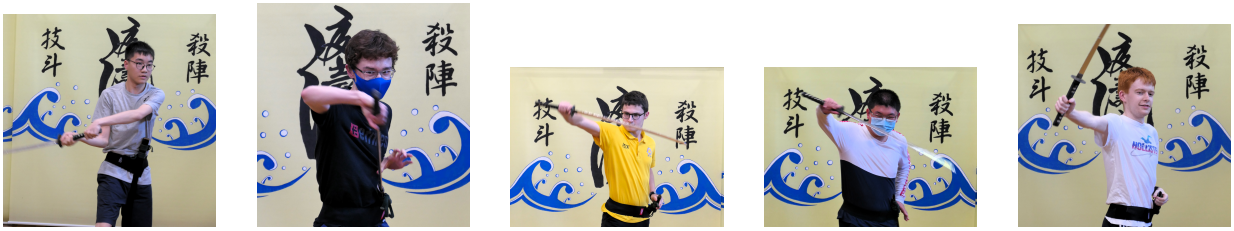


Figure 5: Training to become master swordsmen.

Back at the hotel, Thomas, Alex and Sida discuss C7... really, another instance of a random leap of faith in order to obtain the answer of 3? At dinner, there are these amazing meat dumplings that draw Freddie and Sida in. Emily and Freddie also find some pots labelled ice-cream, but then the receptionist stops them. Initially, we think it's an issue of not having paid for the exclusive items, but after a back-and-forth, it's revealed that the pots are simply the raw ice-cream ingredients, and that they should be put into the machine to actually produce ice-cream.

After dinner, we witness the dying embers of what we assumed was a fiery summer festival, with an elevated platform that Noriko explains is for dancing (with a small demonstration of said dancing with Yuka), and countless stalls all illuminated by ambient red lanterns.

03/07/2023 – F3

The day of reckoning, to see which team has created the most troll paper. Since Dominic was about to leave for the leaders' site, he gives us an inspirational talk just before the F3 exam, leaving us motivated. Yet just a few seconds in, Hadyn adds a correction for AUS $\rightarrow$ UNK P3 with an obscene number of new points introduced to the diagram, and our motivation is washed away. We immediately knew it was another of Chris' abomination geometries.

Figure 6: Wow.

1. P1: A permutations combo involving inversions (no not the geometric kind).
2. P2: $\mathbb{R}^+ \to \mathbb{R}^+$ functional equation.
3. P3: Two-part geometry problem with probably 30-ish points. There were... 'slight' hints to the inspiration of EGMO 2023/2, such as a person named 'Slovenia' and antipodes replaced with 'EGMO point'.

After the exam, Will and Isaac proclaim their dislike toward $\mathbb{R}^+ \to \mathbb{R}^+$ functional equations, whilst Thomas, Sida and Hanks agonise over the hours spent searching for bijections. Alex uses multiple bijections and even lists out all the $n = k = 4$ cases, finishing in the last half hour.

Then it's marking time!

1. AUS $\to$ UNK P1: Chris thought this would be MOHS 10 having solved it in 10 minutes in the shower; boy was he wrong.
2. AUS $\to$ UNK P2: Zian and Sizhe complain about Sida's handwriting, making multiple remarks on his script (however Sida debates that Sizhe's is worse). In comparison, Alex's handwriting is branded as a work of art.
3. AUS $\to$ UNK P3: Chris' intended solution is way over-complicated while Alex and Isaac found much simpler solutions. Then he proceeds to bash Sida for trig bashing the first part.
4. UNK $\to$ AUS P1: Will and Hanks have a relatively smooth time marking, with a variety of constructions, complete and incomplete.
5. UNK $\to$ AUS p2: On the contrary, Thomas and Isaac have an extremely difficult time, grinding through synthetic solutions, trig solutions that end abruptly, and inversion solutions where INVERTED POINTS ARE GIVEN NEW NAMES INSTEAD OF A DASH (you know who you are).
6. UNK $\to$ AUS P3: Conversely, Sida and Alex are pretty chill, giving 0 to multiple scripts including some with only 1 line of rough. Sizhe has the right construction but tried bounding with multiple unknown conjectures at play involving interesting claims

about prime distribution... Chris decides to play it safe and proves that the sum of $1/p$ diverges. He also later finds that this problem was KoMaL A.635 (so technically we do have a KoMaL NT).

After dinner, we play a game of No Thanks, where we collectively agree not to deploy the Aanya strategy of take every card. Somehow a bean ends up missing, and Emily finds it a large distance away from the table. Up next is a game of Cockroach Poker with Hadyn and Michelle. People are classed as either 'lookers' or 'callers', with Sida and Hanks becoming the unyielding callers, and Freddie, Alex the safe lookers. Then at night, we go for a stroll through the other park, with the dark sky and the sound of cicadas creating a gentle environment.

04/07/2023 – F4

With the usual reminder from Hanks about what proportion of the camp has passed, it is time for F4.

1. P1: Synthetic config geo which half the Australians had seen from some handout on American geo, and which Sida inverted with the help of the A-Humpty point (massive overkill).
2. P2: Some wacky integer polynomial problem, which uses the neat fact that if a polynomial only takes integer values, then it is a rational polynomial. There were two opposing factions to proving this: Thomas, Will and Isaac with induction, Alex and Sida with Lagrange interpolation.
3. P3: IMOSL 2022/N6, another magical construction problem yay. It turns out that examining $\{p(n), p(2n-1), p(2n)\}$ (motivation from Sida is RMM 2011/4), which was the approach for everyone who made progress, is a massive bottomless pit that requires some hardcore number theory, yet it felt so right because it removed Q.

For our excursion, we head to an aviation museum. On the journey there, Thomas is curious about Hanks' life at boarding school, and Hanks begins depicting such life with a great amount of detail. Sida is dubbed an 'eshay' for his attire, consisting of a cap that is constantly stolen by Chris and a fanny pack (supposed British translation of 'eshay': a roadman who steals laptops from people and breaks them).

In the museum, we are initially split into halves and alternate between the space flight simulation (where Sizhe and Zian end up crashing) and watching documentaries, initially entirely in Japanese because we were oblivious of the ability to switch languages. Sida and Chris convince themselves that in order to activate the interactive screens, you have to gently caress it. Will debunks this theory by tapping the image.

Then something catches our eyes: a video game simulation, where you try to land a rover as close to the target as possible. Within minutes AUS and UNK are hooked. Multiple turns later, we get bored and start limit testing each of the variables as well as the scope of the simulation. This includes Alex sending the rover *away* from the target as efficiently as possible, resulting in the asteroid shrinking to nothingness.

Figure 7: Live on the scene of the crash.

Then we return to the hotel and play the most insane game of Avalon possibly in the history of the game, with coordination between evils never before seen, in fact so much deception that they themselves are confused. Chris, who keeps pleading his innocence but was the only failed addition to an already failed mission, turns out to be good...

For dinner, some of the UK team go out to an eel place, where Noriko says that Yuka would always have eel the day before a competition. We all agonise over the guaranteed C6 as problem 2, as Freddie and Isaac try to rationalise with us. Unfortunately, Sida has to comment that 'if tomorrow's G8 is going to be a circumscribed inscribed hexagon with a condition then I'm leaving the exam room'... The eel was amazing.

Figure 8: Lovely meal at the eel place!

On the way back, we discuss problems with a combination of topics. Of course, CA, CN, CG, AN are very common. Thomas proposes IMOSL 2021/G3 for AG, and both Sida and Thomas activate their collective hivemind to simultaneously give USAMO 2020/4 for ACGN. Then Hanks proceeds to construct the most horrific CG in existence, with 2023 mutually tangent circles (this may or may not be possible). Finally, to refresh us on the most important Olympiad trick of all, Freddie quizzes us on the prime factorisation of 2023.

05/07/2023 – Ashes

The time has finally arrived. The greatest sporting event of the year. The Mathematical Ashes. Hadyn does all the instructions in Japanese to get us in the mood, and then the games begin.

1. P1: IMOSL 2022/N2, a semi-troll problem.
2. P2: IMOSL 2022/C6. Collectively we wonder how this had become C6, given the unusual difficulty of C5. Nonetheless, for an hour Sida and Thomas both mistake the answer for the sum of digits in base 2 (throwback to IMOSL 2020/C8) before checking the case $n = 7\ldots$
3. P3: IMOSL 2022/G8. Sida definitely jinxed it. Alex and William (to avoid confusion with our Will) have varying solutions. Others including Isaac, Chris and Sizhe reduce the problem using Monge. It turns out there's actually a purely DDIT solution, which validates Sida's use of an hour.

To distract us from the mathematics, we head to a bowling alley after lunch. Forget the Mathematical Ashes, this is where the true competition begins.

As we wait to enter in the mall, we find a guy absolutely demolishing a rhythm game at the arcade. Thomas then tries to get Hanks to remember all the students at the final selection camp (consisting of 10 people), with the rest of the UK team eventually joining in to cheer him on. Alex also debates Sida's claim that most G8's are projective.

To get ready for bowling, we have to switch into bowling shoes, but it turns out that most of our feet are a size larger than the largest size offered, so a compromise is made. When the bowling begins, Hanks unveils his hidden talent as a professional bowler, scoring a strike then a spare in succession. Will is consistent with his bowls, Sida and Alex not so much, whereas Isaac sees a genuinely exponential improvement. Overall it's a great vibe with people cheering and celebrating for each other. In the end, UK beats Aus on average by around 10 points, but it's not about winning, it's about the friends we made along the way. Chris, who initially said 'I just hope I don't get last' literally gets the highest out of everyone.

On the way back, we pause and realise the streets are completely silent, in direct contrast to William and Sizhe's choral singing. At the hotel exam room, the deputy leaders welcome us with anticipation into the exam room, where after an immense build-up of suspense, it is revealed that UK and Aus are tied!

Multiple professional-level photos are taken of us in a group, in a line, shaking hands, etc. Chris is intrigued that he seemingly gained a partial on P3 for mentioning the word 'exsimilicentre', while half of the Australian team gather around Sida's P2 script for a unique approach of proving $(n - 2^{v_2(n)}, 2^{v_2(n)})$ is always reached.

Dinner is at the Chinese place again, and after systematically searching through our mental registers at Trinity Camp, Isaac is the first to mention the final, elusive name.

Fireworks show! It appears to be the anniversary of some event, with fireworks of different shapes (hearts, lips, a car???) and varieties, including some particularly loud ones, 'bangers',

that resonate all the way to your heart. We manage to entertain ourselves by trying to accurately predict when the bangers would explode. Thomas, Hanks and Hadyn also attempt to estimate the distance to the fireworks by angle of elevation and perceived radius. Eventually, it gets quite smoky so we head back. Meanwhile, we give each other troll problems, and Freddie is stumped by the following problem from the USA team at the RMM:

Clearly a square can be cut into n congruent shapes for all square numbers n. For what other values of n is this possible?

We also try to estimate the sum of the IMOSL positions of this year's IMO paper, with our average floating around 24.

Figure 9: Fireworks! This one was not a banger.

To end the day, Freddie introduces us to a roll & draw game called Railroad Ink, where you are given a grid and each turn, a set of dice determine some rail/road connections to add to your grid. Unfortunately, one game wasn't enough to determine the optimal strategy.

06/07/2023 – Arrival at Chiba

Today we set out for Chiba via coach. There are various quizzes going around, some mathematical, some not. At the back of the coach, Chris provides problems from an Australian team challenge, with problems such as approximating $e^\pi - \pi$ (Freddie, Thomas and Sida took 3 attempts) and placing 5 congruent shapes onto a grid with a line of symmetry. As usual, Sizhe and Zian are grinding Plants vs. Zombies. In the middle of the coach, Hadyn, Isaac, Thomas and Will mull over countries with names exhibiting special properties, like all 5 vowels in one word, only one vowel, etc. Thomas manages to get the final word with one vowel given the hint that there is a 100% chance at least two of the UK team have been there before.

Upon arrival, we have lunch at a Cafe in a nearby mall, where some of us try the famous Japanese fruit sandwiches (definitely worth the hype). We head back to the IMO lobby (whilst accidentally spoiling for Thomas the answer to IMO 2010/5) and there we meet our guide, Chad, who is an English teacher at a high school. Then it's merch time, with a fashionable bag containing an umbrella, a friction pen, and an adorable panda plush.

To occupy ourselves whilst we wait, Hanks realises he has forgotten the floor he stays at in Hong Kong, so Thomas and Will try to re-open his mind palace. Their efforts are fruitful, and the magical number is 11. Whilst this was happening, Freddie introduces us to the card game of Yaniv, and then we're joined by Millie from the Swedish team for a game of Sevens, introduced to Will by a Finnish person.

We end up waiting around 3 hours, and oh boy we played a lot of games in that time. A bunch of Geistes, where Sida strengthens Hanks' strategy by now focusing exclusively on the white ghost, and eventually when we get to Avalon, we are all praying for a squish character so we don't require our brains. Hanks develops a negative impression of the game after having to strategise as Merlin in his first 5 games of Avalon ever.

Once we reach our rooms (at floor 11 coincidentally), Ava realises Sida is in a completely different block. This fiasco is caused by a mysterious observer... but everything eventually gets sorted. Just outside and inside the hotel, there are animatronic dinosaurs that make realistic sounds. The foremost question in our minds is why? Nonetheless, it becomes an iconic meeting location.

After dinner, we go for a walk in the general direction of the ocean at an approximately constant pace. This involves crossing a long bridge over traffic, and we get a beautiful view of the grand 50-floor hotel, the Makuhari Messe convention centre, and an outdoor sports venue. Alas, our path to the beach is blocked by a barbed wire fence; even Alex's temptations that the Day 1 and Day 2 papers are on the other side aren't enough to get us to jump over (we do snap some sick pics tho).

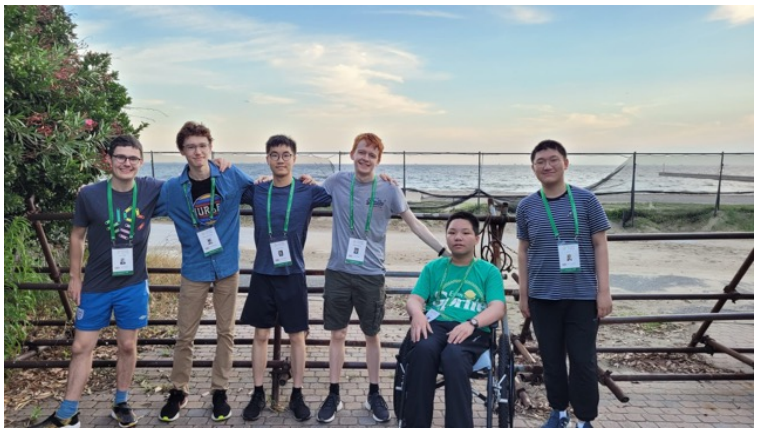


Figure 10: Oh no the papers are on the other side!

Nearby is the Zozomarine Stadium for baseball, with some quotes written on the side that definitely seem Google Translate-d. As we head back, we meet the Hong Kong team, and Alex chats/takes pictures with someone he was on the team with two years ago.

07/07/2023 – Opening Ceremony

The morning starts with a trip to the beach, but it is way too hot and sunny so we abort the mission. On the way Ava teaches us about various flowers and wildlife sounds, and Chad

Figure 11: What does this actually mean?

introduces us to some magical wet wipes. Then he claims that it's most effective under your armpits, but will start to burn. We test that claim.

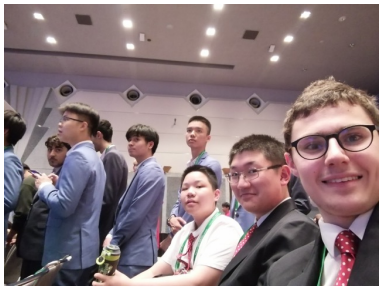
Figure 12: Unfortunately an image doesn't capture the fact that the air is vibrating like in the movies.

Then we head to the Jane Street Hub, this year in the form of the Dragon and Crane rooms. As Freddie puts it, 'Jane Street really knows how to attract students: games and snacks'. The Dragon room contains claw games, air hockey, video games, a bunch of free merchandise, some origami, Jane Street's Figgie game, and of course snacks. Oh boy a lot of snacks, including Mario chocolate lollies and every flavour of KitKat you could imagine. The Crane room, on the other hand, is much more chill. There's a beautiful glass wall to a view, and people are just chilling playing board games. We stay in the Crane room as Isaac introduces us to the game of Camel-Up, which comes with the lengthiest set of instructions. Will catches a glimpse of a person with One Night but couldn't capitalise, so instead Set is played.

In preparation for the opening ceremony, we get absolutely dripped for the occasion, though the blazers were very warm whilst walking to the hall so they were momentarily off. As we

Figure 13: So much KitKat variety.

are waiting in the hall, Hanks, Will and Thomas play some Old Maid, while Isaac and Alex get rid of their boredom with Hex. Alex and Sida also play 'Spot the Typo' in the seating arrangement depicted on the big screen. On another screen there's the same series of videos played over and over to the point where we could predict the next sentence. In particular, there was an interesting insurance ad which tried to be poetic, including phrases such as 'We love insurance as much as you love your family'.



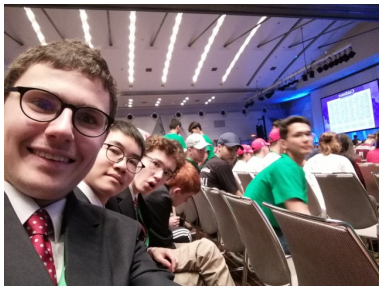


Figure 14: Isaac selfies.

The opening ceremony begins. We are immediately given a traditional drumming performance; it genuinely gets the heart thumping, though this was possibly due to the sheer volume. Then the MOS Brass group absolutely shred some anime songs, with the drummer delivering a jaw-dropping solo towards the end. Following that, we have a few speeches from some important people, and finally the event we were waiting for: team presentation. Notable events include a 'Shinzo Sasageyo!' from Iran, and a three-part football trilogy of a Messi plush from Argentina, a 'SIU' from Portugal and a 'Shaqiri > {Pessi, Penaldo}' shirt from Switzerland.

During dinner, we puzzle over the wildly inefficient Jane Street Rubiks cube as well as the letter puzzle on the tiles. Will then gets a bunch of bananas to fuel his mathematical adventures.

Figure 15: Coldest fit.

08/07/2023 – IMO Day 1

Our breakfast comes in the form of neat bento boxes, with a bunch of tiny side dishes, but definitely a few too many rice balls this early in the morning. As we wait outside the exam hall, there is this lovely lady who runs around asking every 20 seconds for people to 'Hurry up', though initially we thought she was speaking Japanese. She becomes quite the icon throughout the event. Inside the hall, our plastic wallets get analysed, Freddie gives us a pep talk, and we head to our seats. There's a giant screen at the front, and double-wide desks in a grand lattice with lots of space in between. Will, Hanks and Thomas go around bidding people good luck right before we're told to stay in our seats. Then, the exam begins.

1. P1: Neat little number theory. Sida and Isaac deploy v_p whereas Alex induction.
2. P2: Problem 2 geo?? Is this real life, or is this just fantasy?? Multiple synthetic approaches exist, but somehow Sida finds one that is essentially a massive cross-ratio chase, and Thomas reduces the problem to something length-bashable by a ratio lemma.
3. P3: Sequences or polynomials... turns out it's sequences, with way too many uses of infinite pigeonhole.

Alex and Will claim solutions to P3, whereas Isaac and Sida claim most of a solution, with errors arising from rushing. Sida then realised he forgot to prove a claim in his P2 proof that is identical to his other claim (also trivial by Reim anyway smh), and prays for a nice mark scheme.

After trying out the elevator straight up to the 46th floor, we head to the park with the Australian team. Sida laments that once again, he missed the easy case (proving decomposition into linear factors implies arithmetic progression), and Alex teases him for it once

again. Hanks and Thomas play a game where they try to create the most creative triangle centres, as inspired by BMO3 at Trinity Camp. Chris joins in mid-way, noting that one of the random centres they mentioned was something like X-54 in the online encyclopedia. There is a woman in a kimono with a professional photographer, and Chad explains that this is likely her coming-of-age ceremony. Another team asks if they can take a photo with her, and she agrees.

Figure 16: One with nature.

Then we find a children's playground, and naturally this means William and Sizhe have to join in. Unfortunately, there is an age limit, so they and Isaac proceed to the nearby outdoor gym to attempt pull-ups. Chris and Sida partake in a two-player Maker-Breaker game where Chris tries to push Sida into the grass while Sida tries to get off.

Back at the hotel, we find the Netherlands team, including Allie who has a copy of One Night, as well as the original Werewolf. As we play the original, where the DLC includes 50 new roles, we learn that the Netherlands team is selected first by height, then by apple juice-drinking ability, and least crucially, by mathematical ability. The also introduce the role of Pig, where communication not via pig-tongue results in immediate death.

09/07/2023 – IMO Day 2

Day 2 starts off relatively normal, you know, the usual PACER beep test at the back of the hall with 30–50 students participating, a few arm-wrestling competitions here and there, and of course the spontaneous rounds of applause as people randomly clap to see if everyone would join in (yes).

1. P4: Nice and unique inequality problem.
2. P5: Lovely combi/combo with an interesting flavourtext. It turns out Dilworth's/Mirsky's theorem can provide some useful motivation.
3. P6: 480 degrees??? A menacingly difficult geometry. It turns out a DDIT-based approach (credit to a Danish contestant) could get 2 partials, and even though a bary-bash is possible (one Romanian contestant and the US Deputy Carl managed to do it), it's very hard to approach.

There's no significant progress on P6 for anyone, but a very high number of P4, P5 solves despite their difficulty. Will, by a significant margin, wins the award for the largest number of sheets of paper per problem, with 30 pages for P5. Sida had a bad day and got stuck on P4, but realised afterwards his heavily-rushed work resembles a novel calculus-based solution.

Figure 17: Hanks' amazing hair in the wind.

Dominic arrives at Makuhari from the leaders' hotel, and this time we actually step onto the beach! In direct contrast to the unyielding sun earlier this week, it's exceptionally windy today and we see people kite-surfing, literally flying into the air. Hanks' hair goes crazy.

10/07/2023 – Disneyland

It's an early start for Disneyland, meeting for breakfast at 7:10am. On the trip there we are greeted by the grand, fancy castle-style hotel, and immediately upon stepping out of the coach, a massive heatwave hits us as we join the queue. To prevent the inevitable annoyance of everyone around, we have avoided playing Contact this entire trip, but eventually we cave in (it has truly become the go-to waiting-in-a-queue game).

Inside Disneyland we are joined by Kumiko, the guide of another team who has been separated, and after taking multiple picturesque photos of the iconic Disney castle, we wander towards the rides. First, we partition ourselves into the 'scary ride' subset, consisting of Chad, Isaac, Sida and Thomas, and the 'casual ride' subset. Due to peer pressure, Hanks decides to join the 'scary ride' subset.

Scary ride gang:

Overall, the queues are much shorter than expected, with the longest being less than an hour. Our first ride is the 'Big Thunder Mountain', a very efficient packing of thrills, via sharp turns, into one short ride. Up next we catch sight of 'Splash Mountain' and have to go; there's a massive build-up depicting the story of Br'er rabbit (though we all had no idea who this was) preparing us for a sudden, approaching vertical drop through water. In the photos afterward, we find Hanks hilariously grabbing onto Isaac for dear life.

Figure 18: Selfie in front of the castle!

Then we are joined by the rest of the UK team for the Mark Twain Riverboat, where we are transported to the gentle rivers of America with hidden surprises in the islands. The best part was waving at people below. Nearby is a dessert vendor, and brandished with our Suica cards, some of us try ordering in Japanese. Sida expected a significantly greater number of Tiramisu ice-cream sandwiches (let this be S) compared to orange ice pops (let this be P), but it ended up with $|P - S| \leq 1$.

Figure 19: Here $P = S + 1$.

After vibing to a parading Baymax float, where Thomas and Sida try to memorise the lyrics (probably annoying Isaac in the process with more than 10 iterations of B-A-Y M-A-X), we head to the long-awaited Pirates of the Carribean ride. It turns out to not be the ride we were expecting, but nonetheless was a genuinely gripping cinematic experience. In search for more thrills, we come across Space Mountain, where we are sent hurling in all directions in a pitch black environment with kaleidoscopic lights.

Our final ride is Star Tours. Thomas' inner Star Wars fanboy shines through, as he goes on a photo spree. Hanks admits to the heinous crimes of not having watched the series before we board the ride, which takes place in a room? The ride assistant says something in Japanese that involves 'the red button', and this sends us into panic that we'll somehow be ejected. A helpful lady informs us that we just need to press the button to check our seatbelt is secured. The ride itself wasn't anything out of the ordinary, we just travel to a few different worlds, escape Kylo Ren, destroy a few star ships, save the day, normal day. Chad notes that C-3PO sounds epic speaking in Japanese.

To end the day, we convene in the shopping area and go searching for souvenirs. Isaac gets a pair of Mickey Mouse ears, whilst Hanks, Sida and Thomas buy a Baymax plush each. Hanks races through the shops with maximum efficiency. When leaving Disneyland, we pass by a final gift shop, and it seemed like this had a longer queue than each of the rides. We get our first taster of Japanese vending machines as Chad recommends us the Pocari Sweat drink, and then we board the train back to Makuhari, tentatively waiting for the Splatoon quiz ad to appear on screen.

As Sida and Alex wait for dinner, a Korean observer approaches them and asks if she can conduct a maths interview. Reluctantly, Sida and Alex agree, and face extremely tough questions like 'What is maths to you?', 'How is maths perceived in your country?' and 'Why is UK maths research good?'. In the evening, multiple games occur, with Thomas and Sida joining some of the Portugal and Netherlands teams in Werewolf, eventually being re-located to a corner of a corridor. In one game, the two werewolves were struck by the Cupid, resulting in a swift civilian win.

11/07/2023 – Excursions

Having decided that a visit to the insurance company wasn't particularly high on anyone's bucket list, Ava and Chad organise a trip into Tokyo. Of course, this means quite a late start, because who wants to wake up at 7am again. At this point we've marked a certain table in the lobby as UK territory, and start with some Rummikub, Hanabi and a few card games. We are all tired of Avalon at this point, with Alex accusing Sida of being evil, Hanks inevitably Merlin, Will also inevitably not squish, Thomas being indecipherable, and Isaac acting sus.

First up on our plan for this sweltering day is Ueno zoo. Ava suggests we focus on animals we can't usually find elsewhere, yet it turns out collectively we have very little zoo experience, so we end up attracted by every non-domesticated animal, such as the elephants, monkeys, penguins, flamingos, and a bison.

Ava says, to celebrate our performance, we get to eat whatever we want this evening, and Hanks, emerging from the barriers of peer pressure, makes an initiative for ramen. On another note, Ava hands us some honeycomb snacks, and we are reminded that there are virtually no rubbish bins in Japan.

We observe a pair of giant pandas called Ri Ri and Shin Shin, but their backs were away from us and they were lying completely still. Isaac correctly claims that the red pandas were

Figure 20: Lazy giant pandas.

much more exciting than the giant pandas. On the way back, we somehow find ourselves in another giant panda exhibit, but this time they have much more energy. We get notice of our official scores via Whatsapp, and they are roughly as expected. Isaac and Chad see if they can sneak in a quick polar bear visit before we depart, but it turns out to be farther than they had hoped.

Second on the Tokyo tour is the famous Skytree. Given our tight schedule, we head to an Italian place for lunch, and Ava notes that we must have been starving since all of us leave with spotless plates. Inside the Skytree, we ascend to 350m, with multiple ear poppings required. Our first priority on the deck was to find Mount Fuji, but unfortunately the fog was too heavy. Upwards we go, making a quick stop before going up a ramp to 450m. Emily and Thomas pose next to some Disney-themed exhibits, and we all try treading over the transparent floor, which wasn't as bad as some of us were expecting.

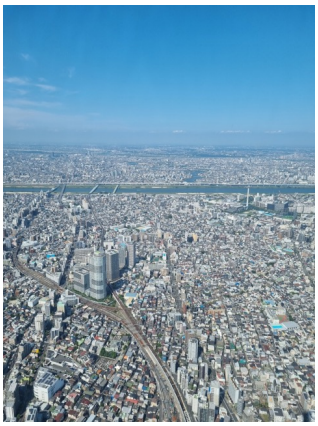


Figure 21: Grand view from the Skytree – no Fuji though.

Of course, a Tokyo tour isn't complete without Asakusa Shrine. It's extremely busy as we stroll through the stalls, selling various foods and souvenirs. Thomas warns us about the danger of buying shirts with foreign characters on it; you have no idea what it means. Dominic buys a green-coloured drink for us to try, and turns out it's macha flavour. We head over to the temple to pray, which involves throwing a coin, a sequence of claps, and

finally the prayer.

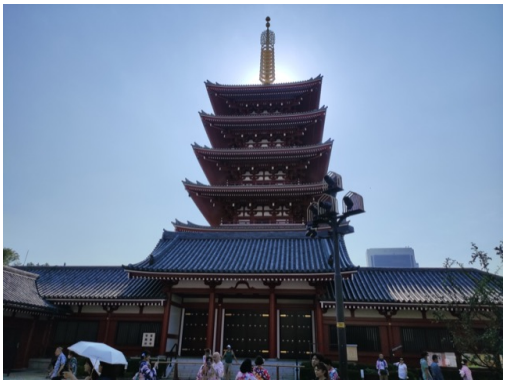


Figure 22: Thomas' stunning photo of a temple illuminated by a beam of sunlight.

The final stop on the tour (Chad's recommendation) is Akhihabara, the centre for all things modern technology and anime. The cabs drop us off just outside an anime collaboration cafe, and we see the streets lined with people advertising maid cafes in cosplay, as well as high-rise buildings with grand advertisements. We are left to explore inside a multi-storey store, where Sida decides to buy a volume of his favourite manga (Oshi No Ko, highly recommend).

Figure 23: Akhihabara – anime galore.

Back outside, we pass by a figurine store where Chad reveals each costs up to hundreds of pounds. Having returned to the cab, we immediately return to maths talk, as Thomas mentions there's a cool fact about isogonal conjugates in polygons (and Sida and Alex both immediately respond that it's iff the feet of the perpendiculars from the point to the sides of the polygon are cyclic, handout link). Then Alex starts going through a few hilarious number theory proofs that ChatGPT produced, including '30 is divisible by every single prime'.

At dinner, Hanks' suggestion of ramen is heeded upon, and we're given a menu where each bowl is provided with a spiciness level as well as a dubious lightning rating... Chad asks the shop owner and informs us it is numb-ness. After we appreciate how efficiently this one person runs the entire store, we start discussing what uniquely makes the UK great, and

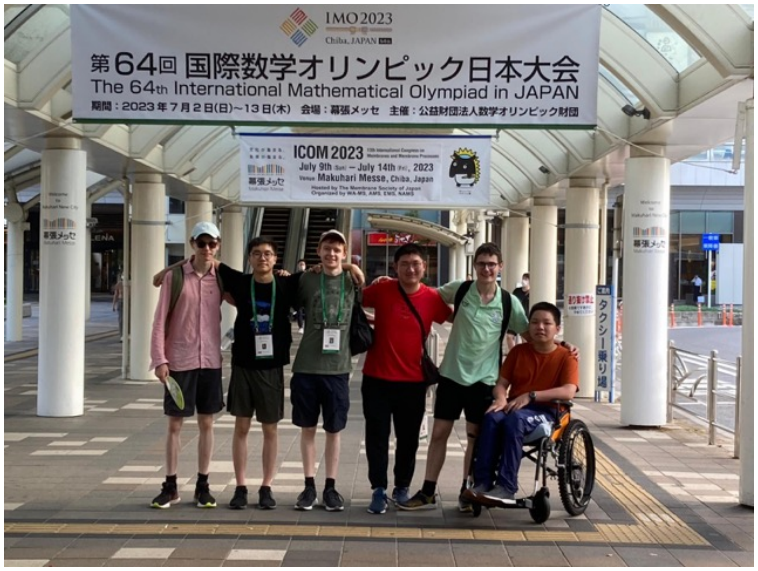


Figure 24: Apparently there was also an International Conference on Membranes and Membrane Processes at Makuhari as well...

surprisingly this is quite the engaging discussion. Food? Well apart from the Full English breakfast, we vetoed this. Literature? Will especially vouched for this, and got us to agree. Tea? No. Weather? Definitely no. Films? Thomas notes that we do have James Bond. Monarchy? Eventually this somehow became a chat about Harry and Meghan, and Ava was overwhelmed with joy as she finally caught us talking about stuff other than maths.

When our food gets served, Will realises there are shrimp pieces in his ramen and broth, and gets it exchanged. Yet the eggs he ordered remained, resulting in a strictly increasing number of eggs until $n = 6$. Dominic and Freddie head to the final Jury meeting, as the rest of us return to the hotel. It is revealed at 10pm that the boundaries are 18/25/32, and Isaac is naturally overwhelmed with joy.

12/07/2023 – Closing Ceremony

We get the morning off to chill in the Dragon Room, which consists of a lot of Rummikub (naturally with a lot of back-stabbing) as well as Pac-man (we may have been mildly addicted). Meanwhile, Freddie and Will head to a stationery store for some souvenirs.

Whilst waiting for lunch, Will takes a picture of the IMO sponsors so he can email them for internships. After lunch, Will and Thomas occupy the time in waiting for room service to finish up by hanging around in Sida's room. Then peer pressure brings Hanks into Sida's room as well. There, Will and Thomas deliver a powerful rendition of the Hamilton soundtrack, receiving a round of applause from their audience.

It's time for the closing ceremony, and after being rushed by the 'Hurry up' lady for the last time, we're designated a first set of seats by score and a second set of seats as the next host of the IMO. Everyone is also given a box to put their medal inside. Fionn from the

Irish team unsuccessfully tries to persuade Sida to move away from the UK to Ireland. The closing ceremony starts off with a nostalgic slideshow of photos taken every day, and then medal presentation occurs, with about 10 people going up at once. Our mental checklist consists of: 1) Get the flag the right way around, 2) Get the medal over the flag.

It seems like the Hungarians went up in their bathrobes? Fionn didn't own an Irish flag so improvised brilliantly with an orange volunteer shirt in one arm and a green on the other, himself wearing a white shirt. Isaac presents himself with indescribable happiness. Then is time for the flag-passing, and Will is designated as the receiver of the IMO flag on stage from the Japanese team.

Up next is the 'short clip' for IMO 2024, except it's 10 minutes long. Yet contrary to Dominic's skepticism on whether the students would find it funny or cringe, we thought it was quite good, with references to China winning, chess 'devices', one room per person, and of course cameos from the UKMT Prime Puzzle book, Geoff Smith, and the aperiodic monotile.

We head to the beautiful 46th floor to take some photos, and what immediately catches our attention is a geometry problem involving Simson lines. After a bunch of photos, a member of the Malaysian IMO team finds Will and asks him 'Do you remember me?' (always a dangerous question). It turns out they were at IOL last year, and Will claims his red hair and pushiness is what makes him memorable.

Figure 25: Team photo on the 46th floor (Simson line problem out of the picture).

Finally it's time for the after-party! We arrive early and Freddie deliberately chooses the table farthest from the loud music, also a table with the luxury of chairs. He then convinces Hadyn to bring the Australians over as well. We find Vesna and Joseph, who leaves again (a mysterious figure). Geoff joins us at the table, and helps us fend off multiple people trying to steal chairs. Isaac goes on a sticker-giving spree, akin to Mohit last year. Queues for food

begin, and Chad recommends the fried soba noodles, so Sida and Thomas decide to start the food queue from the opposite end, grab a plate of those, and swiftly return.

Thus begins the main event of the evening: the band performance. The pianist is a friend of Chad's, and a former IMO participant. Will and Sida join the Bon dancing, a series of traditional dances where you go around slowly in a circle, with the final dance composed by the pianist especially for IMO 2023! It involves p steps where p ranged through all the primes up to 31. Meanwhile, Hanks, Thomas and Alex play card games, and Isaac joins the last vestiges of the dancing.

To round off the night, the UK team go off to play card games, starting with a game of Yaniv with the Japanese team member who delivered the student oath. Sida, Thomas and Hanks join the Belgians and Germans for a game of Mao, and eventually settle on the ground floor of the hotel after being re-located twice. A lot of early Maos result in too many rules to keep track of, and one rule about playing during any turn with three different modular arithmetic restrictions is voted off.

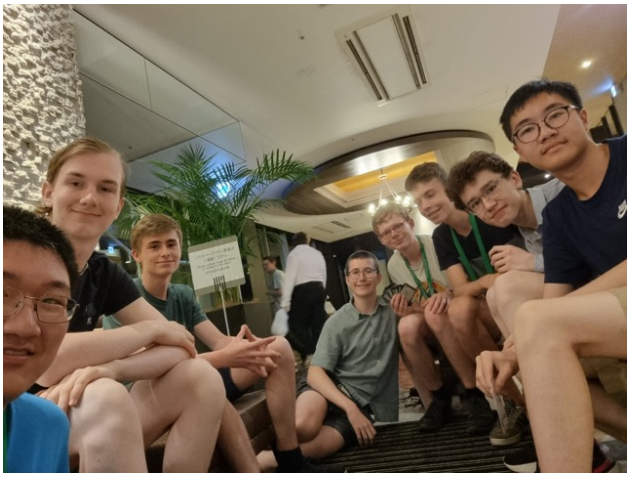


Figure 26: Final game of Mao.

13/07/2023 – Returning Home

After bidding Hanks farewell the night before, we pack our stuff early and head to the coach. Thomas is determined to get the packed breakfast all the way through to the gate, and his efforts are rewarded by the sweet taste of pastry. It turns out that we don't even have to take laptops out of our bags anymore! The wonders of modern technology.

We are joined by the Swedish and Danish teams whilst waiting at the gate, and Ava is super kind to give us each a peach-flavoured KitKat box to take home. On the plane, Sida, Thomas, Isaac and Freddie decide to do a movie-thon, with Isaac and Thomas grinding through the Mission Impossible series, and Sida a few recent Marvel movies.

After setting foot back on English soil, we are welcomed by the picturesque grey skies. At baggage reclaim, we discuss plans for the summer, with various people heading off to various

countries. Finally, our parents come to pick us up as Freddie and Dominic depart by tube. What an adventure.

Thank you

1. Massive thank you to Ava for accompanying us on this trip, and for always ensuring we were comfortable, healthy, and were having fun. Thank you for always being on top of everything, for bearing with us as we spoke mathematical gibberish all day long, and we hope you enjoyed Japan as much we did.
2. Thank you to Freddie for supporting us throughout this trip, for always being there to discuss advice, motivations and feedback, and for arguing for every mark during coordination.
3. Thank you to Dominic for being there for us throughout all these years, for organising training, making us laugh with your amazing sense of humour, and for being an amazing leader.
4. Thank you to Chad, you were an amazing guide in Chiba, always willing to join us and keeping an easygoing attitude throughout the event. We knew that every day, you'd greet us with a 'What's up?' and everything would be organised superbly.
5. Thank you to Noriko for everything in Fuchu; the delicious meals, the fascinating excursions, and the insights into life in Japan really elevated the week. You always had something arranged to keep our minds off the exams and to look forward to, which we massively appreciate.
6. Thank you to Yuka as well for being a lovely guide in Fuchu, and for always being so open to share the wonders of Japanese culture. Your company throughout the two weeks became an invariant comfort.
7. Thank you to the Aussies: Chris, Sizhe, William, Zian, Cloris and Iris. We knew we could always count on you to liven up our days with your chaotic and erratic personalities (we feel sorry for Cloris and Iris for having to deal with the rest of you). In all seriousness, you made this an unforgettable experience.

Figure 27: UK & AUS.

8. Thank you to Kit and Natalie from the UKMT office for never missing a beat in preparation, meaning that the trip could progress impossibly smoothly.
9. Thank you to UKMT in general for providing us with such great opportunities to meet mathematicians from around UK and from around the world, and to further our mathematical abilities. All UKMT events form unforgettable memories and experiences.
10. Thank you to the IMO Board and Jury; this year's paper was wonderful and to organise everything so well on such a grand level must've been a monumental feat. We all enjoyed it.

Figure 28: Thank you!

Appendix 1 - Scores

Code	Name	Q1	Q2	Q3	Q4	Q5	Q6	Total	Result
UNK1	Hanks Chong	7	3	0	7	3	0	20	Bronze Medal
UNK2	Alex Chui	7	7	7	7	7	0	35	Gold Medal
UNK3	Thomas Kavanagh	7	7	1	7	7	0	29	Silver Medal
UNK4	Isaac King	7	7	4	7	7	0	32	Gold Medal
UNK5	Sida Li	7	6	3	4	3	0	23	Bronze Medal
UNK6	William Thomson	7	0	7	7	7	0	28	Silver Medal
-	Total	42	30	22	39	34	0	167	-
UNK7	Dominic Yeo	-	-	-	-	-	-	218	-
UNK8	Freddie Illingworth	-	-	-	-	-	-	1007	-
UNK9	Geoff Smith	-	-	-	-	-	-	3150	-
UNK10	Ava Yeo	-	-	-	-	-	-	7841	-
UNK11	Emily Chow	-	-	-	-	-	-	16811	-
-	Min	7	0	0	4	3	0	14	Honourable Mention
-	Max	7	7	7	7	7	0	35	Gold Medal

Our degree 5 polynomial:

$$\frac{49}{60}x^5 - \frac{115}{8}x^4 + \frac{287}{3}x^3 - \frac{2389}{8}x^2 + \frac{25891}{60}x - 195$$