A REPORT ON THE 29th IMO (9 - 21 JULY, 1988)

P.J. O'Halloran

P.J. O'Halloran was Chairman of the 1988 International Mathematical Olympiad Organising Committee. He is President of the World Federation of National Mathematics Competitions as well as Executive Director of the Australian Mathematics Competition. He is a Principal Lecturer at the Canberra College of Advanced Education.

1. Introductory Comments

The 29th International Mathematical Olympiad was hosted in Australia from 9-21 July, 1988. It was the first time that an IMO was held not only in the southern hemisphere but also in the Asian/Pacific region. A record number of 268 contestants from 49 countries and territories plus representatives from another 9 countries and territories participated. For the first time there were more non-European teams (25) than European teams (24) participating at an IMO.

In all, 120 contestants from 38 of the 49 participating countries achieved medals (17 gold, 38 silver and 65 bronze ... see Table Four, 1988 IMO Distribution of Awards) with a special prize being awarded to a Bulgarian contestant for an outstanding solution to one of the most difficult questions ever set in an Olympiad (see Table One: 1988 IMO Score Frequency/Question and Table Two: Discrimination Factors of 1988 IMO Questions). The 1988 IMO's questions were considered to be more difficult than for the last few Olympiads (see Table Five: Comparison of the 1981 - 1988 IMO Results).

The six questions are given at the end of this article.

A new achievement category created at the Olympiad was an "Honourable Mention" award. This was given to contestants who obtained a perfect score (7 marks) for at least one IMO question and had not received a medal. A pleasing feature of this new award is that, as a result, another 7 countries were named as having team members who had received some recognition.

2. Some 29th IMO Statistics Tables

Another important new feature at the 1988 IMO was a 50-page book of 29th IMO statistics available within 3 hours of the Jury deciding the cut-off scores for the various medals. These statistics include information about previous IMO participation
of contestants (approximately 20%), achievement by age (average scores of contestants' groups decrease with age), discrimination factors of questions, average age of medallists (gold medallists 17.3 years, silver 17.9 years and bronze 17.10 years) and so on.

A flavour of some of the statistics is reflected by the Tables given below. These statistics, the 90 question proposals (and their solutions) which were submitted to the Jury, are included in the 250-page book "An Olympiad Down Under - A Report on the 29th International Mathematical Olympiad in Australia". It costs $A20 (Australia and S. Pacific) and $A24 (elsewhere) and is available from the Australian Mathematics Competition, Canberra CAE, PO Box 1, Belconnen ACT Australia 2616.

**TABLE ONE:**

1988 IMO Score Frequency/Question (268 Candidates)

<table>
<thead>
<tr>
<th>Marks</th>
<th>Number of Contestants per Mark per Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
</tr>
<tr>
<td>0</td>
<td>27</td>
</tr>
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<td>6</td>
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</tr>
<tr>
<td>Mean</td>
<td>3.9</td>
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</table>

*Table One* displays the spread of score frequencies obtained by the contestants for each question. The statistics clearly show the level of difficulty for each question. Of particular interest is the distribution of score frequencies for Question Six. This was one of the more difficult questions in the recent history of the Olympiads.
### Table Two: Discrimination Factors of 1988 IMO Questions

<table>
<thead>
<tr>
<th>Group of Contestants</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th># in Group</th>
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<tbody>
<tr>
<td>Gold Medallists</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.75</td>
<td>17</td>
</tr>
<tr>
<td>Gold and Silver</td>
<td>0.06</td>
<td>0.25</td>
<td>0.69</td>
<td>0.44</td>
<td>0.19</td>
<td>0.63</td>
<td>55</td>
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<tr>
<td>All Medallists</td>
<td>0.34</td>
<td>0.47</td>
<td>0.59</td>
<td>0.66</td>
<td>0.31</td>
<td>0.38</td>
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<tr>
<td>All Contestants</td>
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<td>0.84</td>
<td>0.54</td>
<td>0.76</td>
<td>0.82</td>
<td>0.19</td>
<td>268</td>
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</table>

Table Two gives the biserial discrimination index for each question. To obtain this index, the contestants are first ranked in overall ability. Then for a particular question, the number of marks greater than or equal to 4 for the top 25% of contestants is compared with the bottom 25% of contestants. The index can take values from -1 or +1. A positive value indicates that more contestants in the top group obtained 4 or more marks than contestants in the bottom group. It is considered that questions with discriminating factors of at least 0.4 have discriminated effectively.

In particular, Question One, which had the highest mean score, (see Table One) was also the best overall discriminator. However Question Six which had the lowest mean score, was the worst discriminating question overall but, at the same time, was by far the best discriminator for the gold medallist group of contestants.
**TABLE THREE:**

1988 IMO Mean Scores/Age Group

<table>
<thead>
<tr>
<th>Age as of 1/7/88</th>
<th>Mean Score</th>
<th>+ (Number of Contestants)</th>
<th>Medallists</th>
<th>Non-Medallists</th>
<th>Overall</th>
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<tr>
<td>12</td>
<td>34</td>
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<td>13</td>
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<td></td>
<td>-</td>
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<td>*(1)</td>
<td>-</td>
<td></td>
<td>2.0</td>
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<tr>
<td>15</td>
<td>30.8</td>
<td>*(5)</td>
<td>9.0</td>
<td>*(4)</td>
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<td>*(23)</td>
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<tr>
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<td>24.2</td>
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<td>*(43)</td>
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<tr>
<td>18</td>
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<td>*(52)</td>
<td>6.8</td>
<td>*(52)</td>
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<td>19</td>
<td>24.8</td>
<td>*(8)</td>
<td>6.7</td>
<td>*(15)</td>
<td>13.0</td>
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</table>

* It is believed that this contestant, Terry Tao from Australia, is the youngest ever in the 29 year history of the IMO to receive a gold medal. Incidentally, he obtained silver and bronze medals at the 1987 and 1986 IMOs respectively.

Table Three shows how well the contestants' younger age groups achieved at the Olympiad in comparison with their older peers where the means ranged from 21.1 to 13.0 for the 15 to 19 age groups.

**TABLE FOUR:**

1988 IMO Distribution of Awards

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<tr>
<th>Country</th>
<th>Team Size</th>
<th>Code</th>
<th>Score</th>
<th>Gold</th>
<th>Silver</th>
<th>Bronze</th>
<th>Honourable Mention</th>
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### Table Four Cont'd

**1988 IMO Distribution of Awards**

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Table Four summarises the teams' achievements at the 1988 IMO noting the number of gold, silver and bronze medallists and honourable mentions for each team.
# TABLE FIVE:

## Comparison of the 1981-1988 Results

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<td># Total Medallists</td>
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<td>98</td>
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<td>19%</td>
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<td>9%</td>
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<td># Silver Medallists (range of scores)</td>
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<tr>
<td>(40-34)</td>
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<td>(39-26)</td>
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<td>(41-32)</td>
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<td># Bronze Medallists (range of scores)</td>
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<td>31</td>
<td>57</td>
<td>49</td>
<td>52</td>
<td>48</td>
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<tr>
<td>16%</td>
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<td>25%</td>
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<td># Special Prizes</td>
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The statistics in Table Six show that 53 (or 20%) of the 1988 IMO contestants had participated at 1987 IMO and, of these, 9 received gold, 18 silver and 14 bronze medals with an additional 4 achieving honourable mentions. Also note that the average age of the gold medallists was 17 years 3 months, silver medallists 17 year 9 months while the overall average age of the contestants was 17 years 10 months.
TABLE SEVEN:
The IMO - The Spread To All Continents

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There was no Olympiad in 1980

The dominance of European participation in the early years of the IMO is clearly shown. With greater international involvement this dominance has been reduced until in 1988, for the first time in the history of the IMO, more than 50% of the competing countries were non-European. The IMO has truly become a world-wide international annual event.
TABLE EIGHT:

The IMO - A Contest For All Continents

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This Table shows for each IMO participating country, its first year at an Olympiad (Y), the number of times it has participated (P) and the number of times it has hosted an IMO (H).

3. Conclusion

In conclusion it should be emphasised that besides the discovering, encouraging and challenging of mathematically gifted school students, the Olympiads aim at the fostering of friendly international relations between teachers and students. It is believed that both these aims were achieved at this year's IMO in Canberra, Australia.

P. J. O'Halloran,
Chairman, 1988 IMO Organising Committee,
School of Information Sciences and Engineering,
Canberra College of Advanced Education,
P. O. Box 1, Belconnen, ACT, 2616,
Australia.
English version

FIRST DAY
Canberra, July 15, 1988

1. Consider two coplanar circles of radii \( R \) and \( r \) \((R > r)\) with the same centre. Let \( P \) be a fixed point on the smaller circle and \( B \) a variable point on the larger circle. The line \( BP \) meets the larger circle again at \( C \). The perpendicular \( l \) to \( BP \) at \( P \) meets the smaller circle again at \( A \) (if \( l \) is tangent to the circle at \( P \) then \( A = P \)).
   (i) Find the set of values of \( BC^2 + CA^2 + AB^2 \).
   (ii) Find the locus of the midpoint of \( AB \).

2. Let \( n \) be a positive integer and let \( A_1, A_2, \ldots, A_{2n+1} \) be subsets of a set \( B \). Suppose that
   (a) each \( A_i \) has exactly \( 2n \) elements,
   (b) each \( A_i \cap A_j (1 \leq i < j \leq 2n + 1) \) contains exactly one element, and
   (c) every element of \( B \) belongs to at least two of the \( A_i \).
For which values of \( n \) can one assign to every element of \( B \) one of the numbers 0 and 1 in such a way that each \( A_i \) has 0 assigned to exactly \( n \) of its elements?

3. A function \( f \) is defined on the positive integers by
   \[
   f(1) = 1, \quad f(3) = 3, \\
   f(2n) = f(n), \\
   f(4n + 1) = 2f(2n + 1) - f(n), \\
   f(4n + 3) = 3f(2n + 1) - 2f(n),
   \]
   for all positive integers \( n \).
Determine the number of positive integers \( n \), less than or equal to 1988, for which \( f(n) = n \).

Time: 4.5 hours
Each problem is worth 7 points.
4. Show that the set of real numbers $x$ which satisfy the inequality
\[
\sum_{k=1}^{70} \frac{k}{x-k} \geq \frac{5}{4}
\]
is a union of disjoint intervals, the sum of whose lengths is 1988.

5. $ABC$ is a triangle right-angled at $A$, and $D$ is the foot of the altitude from $A$. The straight line joining the incentres of the triangles $ABD$, $ACD$ intersects the sides $AB$, $AC$ at the points $K$, $L$ respectively. $S$ and $T$ denote the areas of the triangles $ABC$ and $AKL$ respectively. Show that $S \geq 2T$.

6. Let $a$ and $b$ be positive integers such that $ab + 1$ divides $a^2 + b^2$. Show that \(\frac{a^2 + b^2}{ab + 1}\) is the square of an integer.

Time: 4.5 hours
Each problem is worth 7 points.