

MATHEMATICS

A TABLE OF PARTITIONS INTO TWO SQUARES WITH AN APPLICATION TO RATIONAL TRIANGLES.

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1. *Introduction.* In order to solve a specific problem on rational triangles, mentioned in section 3, a table was needed of all partitions of a number n into two squares according to

$$(1. 1) \quad n = p^2 + q^2$$

for n up to many thousands. C. E. BICKMORE and O. WESTERN ¹⁾ gave such a table but only for n up to 1000, whereas M. RIGNAUX ²⁾ announced a manuscript table up to $n = 10000$ that is, however, not published to our knowledge. Therefore, such a table was prepared that is reproduced here in full.

2. *Preparation of the table.* It is well known, which numbers n can be written in the form (1. 1). In fact they are exactly the numbers that have no prime factors of the form $4k + 3$ to an odd power. Also the number of partitions can be determined without difficulty for each n whose factors are known but the determination of the actual partitions, though straightforward, is rather tedious. In constructing a table of some size, one better starts, therefore, from the right hand side of (1. 1).

On a National accounting-machine an auxiliary double-entry table of n was made by building up from a constant second difference for $p^2 + q^2 \leq 10000$. Twelve columns were produced simultaneously. From this auxiliary table the wanted one was constructed by rewriting the partitions p , q as function of n . This table was first checked against omissions by counting the number of partitions in both tables between round values of n , and next against reproduction errors by verifying that (1. 1) holds for all entries. The same checks were applied to the manuscript for the printer (that had to be arranged in another way) and to the proofsheets.

The table is arranged in six lines of three columns each. The first column gives n , the second and third p and q . In case of double and multiple partitions the argument n is not repeated in order to facilitate their recognition.

¹⁾ C. E. BICKMORE and O. WESTERN, *Messenger Math.* 41, 52–64 (1911).

²⁾ M. RIGNAUX, *L'intermédiaire des math.*, 25, 143 (1918), 26, 54–55 (1919).

3. *An application of the table in the field of rational triangles.* An application of this table, which was in fact the immediate cause for its construction, is the finding of the "smallest" triangle (a, b, c) with integer sides a, b and c and three rational medians. Here, by definition, a triangle (a, b, c) is smaller than another triangle (A, B, C) , where $a \leq b \leq c$, and $A \leq B \leq C$, if either $c < C$ or $c = C$ and $b < B$ or $c = C, b = B$ and $a < A$. L. EULER³⁾ has given already some examples of these triangles, the smallest of which is (68, 85, 87). Several others have been found later on and by following the method of J. H. J. ALMERING⁴⁾ arbitrarily many can be constructed without difficulty. This method, however, does not permit to state what is the smallest solution, but the fact that nobody ever found a smaller triangle than EULER's one, mentioned above, induces the hypothesis, that it is indeed the smallest one.

Of course, for the prove of this hypothesis, it has only to be verified that no smaller triangle than (68, 85, 87) has three rational medians, but the amount of smaller triangles is excessive. It shall be shown, however, that by the use of the table this verification is only a minor computing job.

Be A, B and C the double medians on the sides a, b and c respectively (so that c and C are diagonals of the parallelogram with sides a and b , etc.). They follow from

$$(3.1) \quad 2a^2 + 2b^2 - c^2 = C^2,$$

$$(3.2) \quad 2a^2 - b^2 + 2c^2 = B^2,$$

$$(3.3) \quad -a^2 + 2b^2 + 2c^2 = A^2.$$

If a, b and c are all odd, or if a and b are even, and c is odd, then $C^2 \equiv 3 \pmod{4}$, so C is irrational. If a, b and c are all even, $a/2, b/2, c/2$ are integers and define a smaller triangle. Without loss of generality it can, therefore, be assumed that a and b are odd and c is even. Then (3.1) can be written in the form

$$(3.4) \quad \left(\frac{-a+b}{2}\right)^2 + \left(\frac{a+b}{2}\right)^2 = \left(\frac{c}{2}\right)^2 + \left(\frac{C}{2}\right)^2 = n,$$

where all terms between brackets are integers. Moreover, the inequalities of the triangle require $(-a+b)/2 < c/2 < (a+b)/2$. Hence, n is a number permitting a double partition, and possible values of n are found directly by inspection of the table. As for the smallest triangle certainly holds $a \leq 85, b \leq 87, n = (a^2 + b^2)/2 \leq 7397$.

If a number n to be investigated has the partitions $n = p^2 + q^2 = r^2 + s^2$, with $p < q, r < s$ and $p < r < q$ then is also $p < s < q$. Therefore, each double partition with $r \neq s$ gives rise to two triangles, viz. $(-p+q, p+q, 2r)$ and $(-p+q, p+q, 2s)$.

³⁾ L. EULER, *Novi Comm. Acad. Petrop.*, 18, 171 (1773).

⁴⁾ J. H. J. ALMERING, "Rationaliteitseigenschappen in de vlakke meetkunde", Thesis (1950), Amsterdam.

Not all double partitions come into consideration, however. As a and b are odd, n is also odd. In particular, the case $r = s$ cannot occur. Also cases where p, q, r, s have a factor in common may be rejected.

In this way only a rather limited amount of values of n need a closer investigation. For those n the corresponding a, b and c were computed and inserted into (3. 2). In the few cases that B^2 proved to be the square of an integer, they were also inserted into (3. 3), and in only one case A^2 was the square of an integer, viz. in that of EULER'S triangle (68, 85, 87). This verification was checked by complete duplication. Hence, the smallest triangle with integer sides and three rational medians is (68, 85, 87).

4. *Acknowledgement.* I am indebted to Mr H. DUPARC for useful suggestions, to Miss G. BOTTERWEG, Miss P. M. HEINSEN and Miss R. D. M. MULDER for performing the necessary calculations and to Miss C. LANGEREIS for the preparation of the manuscript.

0	0	0		8	9	305	4	17	464	8	20	628	12	22		8	27
1	0	1	146	5	11			7	466	5	21	629	2	25	794	13	25
2	1	1	148	2	12	306	9	15	468	12	18		10	23	797	11	26
4	0	2	149	7	10	313	12	13	477	6	21	634	3	25	800	4	28
5	1	2	153	3	12	314	5	17	481	9	20	637	14	21		20	20
8	2	2	157	6	11	317	11	14		15	16	640	8	24	801	15	24
9	0	3	160	4	12	320	8	16	482	11	19	641	4	25	802	19	21
10	1	3	162	9	9	324	0	18	484	0	22	648	18	18	808	18	22
13	2	3	164	8	10	325	1	18	485	1	22	650	5	25	809	5	28
16	0	4	169	0	13			6		14	17		11	23	810	9	27
17	1	4		5	12			10	488	2	22		17	19	818	17	23
18	3	3	170	1	13	328	2	18	490	7	21	653	13	22	820	6	28
20	2	4		7	11	333	3	18	493	3	22	656	16	20		12	26
25	0	5	173	2	13	337	9	16		13	18	657	9	24	821	14	25
	3	4	178	3	13	338	7	17	500	4	22	661	6	25	829	10	27
26	1	5	180	6	12		13	13		10	20	666	15	21	832	16	24
29	2	5	181	9	10	340	4	18	505	8	21	673	12	23	833	7	28
32	4	4	185	4	13		12	14		12	19	674	7	25	841	0	29
34	3	5		8	11	346	11	15	509	5	22	676	0	26		20	21
36	0	6	193	7	12	349	5	18	512	16	16		10	24	842	1	29
37	1	6	194	5	13	353	8	17	514	15	17	677	1	26	845	2	29
40	2	6	196	0	14	356	10	16	520	6	22	680	2	26		13	26
41	4	5	197	1	14	360	6	18		14	18		14	22		19	22
45	3	6	200	2	14	361	0	19	521	11	20	685	3	26	848	8	28
49	0	7		10	10	362	1	19	522	9	21		18	19	850	3	29
50	1	7	202	9	11	365	2	19	529	0	23	689	8	25		11	27
	5	5	205	3	14		13	14	530	1	23		17	20		15	25
52	4	6		6	13	369	12	15		13	19	692	4	26	853	18	23
53	2	7	208	8	12	370	3	19	533	2	23	697	11	24	857	4	29
58	3	7	212	4	14		9	17		7	22		16	21	865	9	28
61	5	6	218	7	13	373	7	18	538	3	23	698	13	23		17	24
64	0	8	221	5	14	377	4	19	541	10	21	701	5	26	866	5	29
65	1	8		10	11		11	16	544	12	20	706	9	25	872	14	26
	4	7	225	0	15	386	5	19	545	4	23	709	15	22	873	12	27
68	2	8		9	12	388	8	18		16	17	712	6	26	877	6	29
72	6	6	226	1	15	389	10	17	548	8	22	720	12	24	881	16	25
73	3	8	229	2	15	392	14	14	549	15	18	722	19	19	882	21	21
74	5	7	232	6	14	394	13	15	554	5	23	724	18	20	884	10	28
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82	1	9	241	4	15		12	16	565	6	23		14	23		19	23
85	2	9	242	11	11	401	1	20		9	22	729	0	27	898	13	27
	6	7	244	10	12	404	2	20	569	13	20	730	1	27	900	0	30
89	5	8	245	7	14	405	9	18	576	0	24		17	21		18	24
90	3	9	250	5	15	409	3	20	577	1	24	733	2	27	901	1	30
97	4	9		9	13	410	7	19	578	7	23	738	3	27		15	26
98	7	7	256	0	16		11	17		17	17	740	8	26	904	2	30
100	0	10	257	1	16	416	4	20	580	2	24		16	22	905	8	29
	6	8	260	2	16	421	14	15		16	18	745	4	27		11	28
101	1	10		8	14	424	10	18	584	10	22		13	24	909	3	30
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106	5	9	265	3	16		8	19		12	21	754	5	27	916	4	30
109	3	10		11	12		13	16	586	15	19		15	23	922	9	29
113	7	8	269	10	13	433	12	17	592	4	24	757	9	26	925	5	30
116	4	10	272	4	16	436	6	20	593	8	23	761	19	20		14	27
117	6	9	274	7	15	441	0	21	596	14	20	765	6	27		21	22
121	0	11	277	9	14	442	1	21	601	5	24		18	21	928	12	28
122	1	11	281	5	16		9	19	605	11	22	769	12	25	929	20	23
125	2	11	288	12	12	445	2	21	610	9	23	772	14	24	932	16	26
	5	10	289	0	17		11	18		13	21	773	17	22	936	6	30
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130	3	11	290	1	17	450	3	21	613	17	18	778	7	27	941	10	29
	7	9		11	13		15	15	617	16	19	784	0	28	949	7	30
136	6	10	292	6	16	452	14	16	625	0	25	785	1	28		18	25
137	4	11	293	2	17	457	4	21		7	24		16	23	953	13	28
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145	1	12	298	3	17	461	10	19	626	1	25	793	3	28	961	0	31

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964	8 30		15 30	1297	1 36	1458 27 27	1625	5 40	1789	5 42
965	2 31	1129	20 27	1300	2 36	1460 4 38		16 37	1796	14 40
	17 26	1130	13 31		12 34			20 35	1800	6 42
968	22 22		17 29		20 30	1465 13 36		28 29		30 30
970	3 31	1138	7 33	1301	25 26		1629	27 30	1801	24 35
	21 23	1145	11 32	1305	3 36	1466 25 29	1636	6 40	1802	11 41
976	20 24		19 28		24 27	1469 5 38	1637	26 31		29 31
977	4 31	1152	24 24	1306	9 35		1640	14 38	1805	19 38
980	14 28	1153	8 33	1312	4 36	1476 24 30		22 34	1808	28 32
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985	12 29	1156	0 34		23 28		1649	7 40		21 37
	16 27		16 30	1314	15 33	1481 16 35		25 32	1813	7 42
986	5 31	1157	1 34	1321	5 36	1489 20 33	1657	19 36	1818	27 33
	19 25		14 31	1322	19 31	1490 11 37	1658	17 37	1825	12 41
997	6 31	1160	2 34	1325	10 35		1664	8 40		15 40
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	18 26	1165	3 34		22 29	1493 7 38		24 33	1828	8 42
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	13 29	1170	9 33	1345	7 36	1513 12 37	1681	0 41	1845	9 42
1013	22 23		21 27		16 33			9 40		18 39
1017	21 24	1172	4 34	1346	11 35	1514 17 35	1682	1 41	1849	0 43
1018	17 27	1181	5 34	1348	18 32	1517 19 34		29 29	1850	1 43
1021	11 30	1184	20 28	1352	14 34		1684	28 30		13 41
1024	0 32	1186	15 31		26 26	1521 0 39	1685	2 41		25 35
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1033	3 32	1201	24 25	1369	0 37		1693	18 37	1861	30 31
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1069	13 30	1234	3 35	1402	21 31	1568 28 28	1733	17 38		23 37
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	17 28	1241	4 35		26 27		1741	29 30	1906	15 41
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1952	4 44	2122	21 41		21 43	2452	34 36	2617	4 51	2789	17 50
1954	27 35	2125	3 46	2293	23 42	2458	33 37	2621	11 50	2792	26 46
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	19 40		30 35	2305	1 48		23 44		15 49	2804	10 52
1962	21 39	2129	23 40		28 39		28 41	2628	18 48	2809	0 53
1970	11 43	2132	4 46	2306	25 41	2466	21 45	2633	28 43		28 45
	17 41		14 44	2308	2 48	2468	32 38	2637	6 51	2810	1 53
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	26 36	2138	17 43	2312	14 46	2474	25 43	2644	12 50	2813	2 53
1973	23 38	2141	5 46		34 34	2477	19 46	2645	23 46		37 38
1985	7 44	2146	11 45	2313	3 48	2482	9 49	2650	7 51	2817	36 39
	31 32		25 39	2314	17 45		31 39		21 47	2818	3 53
1989	15 42	2152	6 46		33 35	2493	27 42		25 45	2824	18 50
	30 33	2153	28 37	2320	4 48	2498	17 47	2657	16 49	2825	4 53
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1994	25 37	2164	20 42	2329	5 48		14 48	2665	8 51		35 40
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2000	8 44		22 41	2330	11 47	2501	1 50		27 44	2833	23 48
	20 40	2169	12 45		31 37		10 49		36 37	2834	5 53
2005	18 41	2173	18 43	2333	22 43	2504	2 50	2669	13 50		25 47
	22 39		27 38	2336	20 44	2509	3 50		35 38	2836	30 44
2009	28 35	2176	24 40	2340	6 48		22 45	2677	34 39	2837	34 41
2017	9 44	2178	33 33		24 42	2512	24 44	2682	9 51	2842	21 49
2018	13 43	2180	8 46	2341	15 46	2516	4 50	2689	33 40	2845	6 53
2020	16 42		32 34	2344	30 38		20 46	2690	17 49		27 46
	24 38	2186	31 35	2349	18 45	2521	35 36		29 43	2848	12 52
2025	0 45	2192	16 44	2353	7 48	2522	11 49	2692	24 46	2853	33 42
	27 36	2194	13 45		12 47		29 41	2693	22 47	2857	16 51
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2042	19 41		19 43		23 43	2536	6 50		32 41	2880	24 48
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	31 33	2221	14 45	2389	25 42	2557	21 46	2725	15 50		37 39
2053	17 42	2225	4 47	2393	32 37	2560	16 48		18 49	2896	36 40
2056	30 34		17 44	2401	0 49	2561	25 44		31 42	2897	31 44
2057	11 44		25 40	2402	1 49		31 40	2729	5 52	2900	14 52
2061	6 45	2228	28 38	2404	10 48	2564	8 50	2738	23 47		20 50
2066	29 35	2234	5 47	2405	2 49	2570	13 49		37 37		28 46
2069	25 38	2237	11 46		14 47		19 47	2740	6 52	2906	35 41
2074	7 45	2245	6 47		17 46	2578	27 43		36 38	2909	10 53
	15 43		33 34		31 38	2581	9 50	2741	25 46		2916 0 54
2080	12 44	2248	22 42	2410	3 49		30 41	2745	12 51		2917 1 54
	28 36	2249	20 43		27 41	2592	36 36		21 48		2920 2 54
2081	20 41		32 35	2417	4 49	2593	17 48	2746	35 39		34 42
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