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A table of partitions into two squares with an  
application to rational triangles

BY

A. VAN WIJNGAARDEN

(REPORT R 68 OF THE COMPUTATION DEPARTMENT  
OF THE MATHEMATICAL CENTRE AT AMSTERDAM)

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

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A. VAN WIJNGAARDEN

(Report R 68 of the Computation Department of the Mathematical Centre at Amsterdam)

(Communicated by Prof. D. VAN DANTZIG at the meeting of April 29, 1950)

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 <sup>1)</sup> gave such a table but only for  $n$  up to 1000, whereas M. RIGNAUX <sup>2)</sup> 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.

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

<sup>2)</sup> 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. EULER<sup>3)</sup> 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. ALMERING<sup>4)</sup> 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  $(-p+q, p+q, 2s)$ .

<sup>3)</sup> L. EULER, *Novi Comm. Acad. Petrop.*, 18, 171 (1773).

<sup>4)</sup> 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				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	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	509	5	22	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		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	
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52	4	6		6	13	369	12	15		13	19	692	4	26	853	18	23	
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58	3	7	212	4	14			9		7	22		16	21	865	9	28	
61	5	6	218	7	13	373	7	18	538	3	23	698	13	23		17	24	
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	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	
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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	565	6	23		14	23		19	23	
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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	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	
104	2	10	261	6	15	425	5	20	585	3	24	746	11	25	914	17	25	
106	5	9	265	3	16			8		12	21	754	5	27	916	4	30	
109	3	10		11	12			13	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	
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128	8	8		8	15	449	7	20	612	6	24	776	10	26	937	19	24	
130	3	11	290	1	17	450	3	21	613	17	18	778	7	27	941	10	29	
	7	9		11	13			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	
144	0	12	296	10	14	458	13	17		15	20	788	2	28	954	15	27	
145	1	12	298	3	17	461	10	19	626	1	25	793	3	28	961	0	31	

962	1 31	1124	10 32	1289	8 35	19 33	1620	18 36	1781	10 41
	11 29	1125	6 33	1296	0 36	1453 3 38	1621	10 39		25 34
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	26 28		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	21 32	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	10 37	1640	14 38	1805	19 38
980	14 28	1153	8 33	1312	4 36	1476 24 30		22 34	1808	28 32
981	9 30	1154	23 25	1313	17 32	1480 6 38	1642	11 39	1810	17 39
985	12 29	1156	0 34		23 28	18 34	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	23 31	1664	8 40		15 40
1000	10 30		22 26		13 34	1492 14 36	1665	12 39		23 36
	18 26	1165	3 34		22 29	1493 7 38		24 33	1828	8 42
1009	15 28		18 29	1332	6 36	1508 8 38	1666	21 35	1832	26 34
1010	7 31	1168	12 32	1341	21 30	22 32	1669	15 38	1844	20 38
	13 29	1170	9 33	1345	7 36	1513 12 37	1681	0 41	1845	9 42
1013	22 23		21 27		16 33	27 28		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	26 29	1684	28 30		13 41
1024	0 32	1186	15 31		26 26	1521 0 39	1685	2 41		25 35
1025	1 32	1189	10 33	1354	25 27	15 36		23 34	1853	2 43
	8 31		17 30	1360	8 36	1522 1 39	1690	3 41		22 37
	20 25	1192	6 34		24 28	1525 2 39		13 39	1856	16 40
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1033	3 32	1201	24 25	1369	0 37	25 30	1693	18 37	1861	30 31
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	19 26	1205	7 34	1370	1 37	21 33	1697	4 41	1865	4 43
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1053	18 27		14 32	1381	15 34	1549 18 35	1714	25 33	1882	19 39
1058	23 23	1224	18 30	1384	22 30	1552 16 36	1717	6 41	1885	6 43
1060	6 32	1225	0 35	1385	4 37	1553 23 32		14 39		11 42
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	17 28	1241	4 35		26 27	27 29	1741	29 30	1906	15 41
1076	20 26		20 29	1409	25 28	1573 22 33	1744	12 40	1908	12 42
1082	11 31	1249	15 32	1412	16 34	1576 26 30	1745	8 41	1913	8 43
1088	8 32	1250	5 35	1413	18 33	1585 8 39		28 31	1921	20 39
1089	0 33		17 31	1417	11 36	17 36	1746	15 39		25 36
1090	1 33		25 25		24 29	1586 19 35	1753	27 32	1922	31 31
	19 27	1252	24 26	1418	7 37	25 31	1754	23 35	1924	18 40
1093	2 33	1256	10 34	1421	14 35	1588 12 38	1762	9 41		30 32
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1105	4 33		19 30	1440	12 36	24 32	1768	2 42	1933	13 42
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	12 31	1274	7 35	1445	1 38	1602 9 39	1769	13 40	1937	1 44
	23 24	1277	11 34		17 34	1604 2 40		20 37		16 41
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1109	22 25	1282	21 29	1448	2 38	1613 13 38	1777	16 39		28 34
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1949	10 43		26 38	2290	9 47		35 35	2612	26 44		32 42
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
1960	14 42		10 45	2297	19 44	2465	8 49	2624	32 40	2797	14 51
1961	5 44		19 42	2304	0 48		16 47	2626	5 51	2801	20 49
	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
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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
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	30 33	2153	28 37	2320	4 48	2498	17 47	2657	16 49	2825	4 53
1993	12 43	2161	15 44		32 36	2500	0 50	2664	30 42		11 52
1994	25 37	2164	20 42	2329	5 48		14 48	2665	8 51		35 40
1997	29 34	2165	7 46		27 40		30 40		19 48	2826	15 51
2000	8 44		22 41	2330	11 47	2501	1 50		27 44	2833	23 48
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	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
2026	1 45	2196	30 36	2357	26 41	2525	5 50	2696	14 50	2858	7 53
2029	2 45	2197	9 46	2362	29 39		26 43	2701	10 51	2861	19 50
2034	3 45		26 39	2368	8 48		34 37		26 45	2866	29 45
2036	10 44	2205	21 42	2372	16 46	2529	15 48	2704	0 52	2873	8 53
2041	4 45	2209	0 47	2377	21 44	2533	18 47		20 48		13 52
	21 40	2210	1 47	2378	13 47		33 38	2705	1 52		32 43
2042	19 41		19 43		23 43	2536	6 50		32 41	2880	24 48
2045	14 43		23 41	2381	34 35	2545	12 49	2708	2 52	2885	22 49
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