Сумма делителей числа.

Для начало приведём экспериментальный материал (который был получен с помощью программы Derive (по формуле 1.(см.ниже)): для нахождения делителей числа «a», программа делила число «a» на другие числа не превосходящие само число и если остаток от деления был равен 0, то число записывалось как делитель «a». ):

Ниже приведены все делители чисел от 1 до 1000:

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Теперь несложно посчитать и сумму делителей чисел от 1 до 1000(которые тоже были получены с помощью программы Derive (по формуле 2.), теперь делители «a» просто складывались):

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[497, 576]

[498, 1008]

[499, 500]

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[515, 624]

[516, 1232]

[517, 576]

[518, 912]

[519, 696]

[520, 1260]

[521, 522]

[522, 1170]

[523, 524]

[524, 924]

[525, 992]

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[554, 834]

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[556, 980]

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[584, 1110]

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[642, 1296]

[643, 644]

[644, 1344]

[645, 1056]

[646, 1080]

[647, 648]

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[653, 654]

[654, 1320]

[655, 792]

[656, 1302]

[657, 962]

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[660, 2016]

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[717, 960]

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[723, 968]

[724, 1274]

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[727, 728]

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[753, 1008]

[754, 1260]

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[757, 758]

[758, 1140]

[759, 1152]

[760, 1800]

[761, 762]

[762, 1536]

[763, 880]

[764, 1344]

[765, 1404]

[766, 1152]

[767, 840]

[768, 2044]

[769, 770]

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[771, 1032]

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[773, 774]

[774, 1716]

[775, 992]

[776, 1470]

[777, 1216]

[778, 1170]

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[780, 2352]

[781, 864]

[782, 1296]

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[788, 1386]

[789, 1056]

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[792, 2340]

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[796, 1400]

[797, 798]

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[804, 1904]

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[806, 1344]

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[811, 812]

[812, 1680]

[813, 1088]

[814, 1368]

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[816, 2232]

[817, 880]

[818, 1230]

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[829, 830]

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[832, 1778]

[833, 1026]

[834, 1680]

[835, 1008]

[836, 1680]

[837, 1280]

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[839, 840]

[840, 2880]

[841, 871]

[842, 1266]

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[844, 1484]

[845, 1098]

[846, 1872]

[847, 1064]

[848, 1674]

[849, 1136]

[850, 1674]

[851, 912]

[852, 2016]

[853, 854]

[854, 1488]

[855, 1560]

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[857, 858]

[858, 2016]

[859, 860]

[860, 1848]

[861, 1344]

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[876, 2072]

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[898, 1350]

[899, 960]

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[901, 972]

[902, 1512]

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[904, 1710]

[905, 1092]

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[907, 908]

[908, 1596]

[909, 1326]

[910, 2016]

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[913, 1008]

[914, 1374]

[915, 1488]

[916, 1610]

[917, 1056]

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[919, 920]

[920, 2160]

[921, 1232]

[922, 1386]

[923, 1008]

[924, 2688]

[925, 1178]

[926, 1392]

[927, 1352]

[928, 1890]

[929, 930]

[930, 2304]

[931, 1140]

[932, 1638]

[933, 1248]

[934, 1404]

[935, 1296]

[936, 2730]

[937, 938]

[938, 1632]

[939, 1256]

[940, 2016]

[941, 942]

[942, 1896]

[943, 1008]

[944, 1860]

[945, 1920]

[946, 1584]

[947, 948]

[948, 2240]

[949, 1036]

[950, 1860]

[951, 1272]

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[953, 954]

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[955, 1152]

[956, 1680]

[957, 1440]

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[959, 1104]

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[961, 993]

[962, 1596]

[963, 1404]

[964, 1694]

[965, 1164]

[966, 2304]

[967, 968]

[968, 1995]

[969, 1440]

[970, 1764]

[971, 972]

[972, 2548]

[973, 1120]

[974, 1464]

[975, 1736]

[976, 1922]

[977, 978]

[978, 1968]

[979, 1080]

[980, 2394]

[981, 1430]

[982, 1476]

[983, 984]

[984, 2520]

[985, 1188]

[986, 1620]

[987, 1536]

[988, 1960]

[989, 1056]

[990, 2808]

[991, 992]

[992, 2016]

[993, 1328]

[994, 1728]

[995, 1200]

[996, 2352]

[997, 998]

[998, 1500]

[999, 1520]

[1000, 2340]

Теперь посмотрим, все ли числа являются суммой делителей какого-либо числа и есть ли такие числа сумма делителей которых равна (в первых двух сотнях).

Ниже приведена таблица: [[4, 7]](на втором месте сумма делителей, а на первом число с данной суммой делителей) … [[1, 1]], [2] (т.е. нет такого числа с суммой делителей равной двум):

[1,1]

[2]

[2,3]

[3,4]

[5]

[5,6]

[4,7]

[7,8]

[9]

[10]

[11]

[6,12]

[11, 12]

[9,13]

[13,14]

[8,15]

[16]

[17]

[10,18]

[17,18]

[19]

[19.20]

[21]

[22]

[23]

[14,24]

[15,24]

[23,24]

[25]

[26]

[27]

[12, 28].

[29]

[29,30]

[16,31]

[25.31]

[21,32]

[31,32]

[33]

[34]

[35]

[22,36]

[37]

[37,38]

[18,39]

[27, 40]

[41]

[20,42]

[26,42]

[41,42].

[43]

[43,44].

[45]

[46]

[47]

[33,48].

[35,4 8]

[47,48]

[49]

[50]

[51]

[52]

[53]

[34,54]

[53, 54]

[55]

[28,56]

[39.56]

[49,57]

[58]

[59]

[24,60]

[38.60]

[59,60]

[61]

[61,62]

[32,63]

[64]

[65]

[66]

[67]

[67, 68]

[69]

[70]

[71]

[30,72]

[46,72]

[51,72]

[55,72]

[71,72]

[73]

[73,74]

[75]

[76]

[77]

[45,78]

[79]

[57,80]

[79,80]

[81]

[82]

[83]

[44,84]

[65,84]

[83,84]

[85]

[86]

[87]

[88]

[89]

[40, 90]

[58,90]

[89,90]

[36,91]

[92]

[50,93].

[94]

[95]

[42, 96]

[62,96]

[69,96]

[77,96]

[97]

[52,98]

[97,98]

[99]

[100]

[101]

[102]

[103]

[63,104]

[105]

[106]

[107]

[85,108]

[109]

[110]

[111]

[91, 112]

[113]

[74,114],

[115]

[116]

[117]

[118]

[119]

[54,120]

[56,120]

[87,120]

[95,120]

[81,121]

[122]

[123]

[48,124]

[75, 124]

[125]

[68,126]

[82.126]

[64,127]

[9 3,128]

[129]

[130]

[131]

[86,132]

[133]

[134]

[135]

[136]

[137]

[138]

[139]

[76,140]

[141]

[142]

[143]

[66,144]

[70,144]

[94,144]

[145]

[146]

[147]

[178]

[149]

[150]

[151]

[152]

[153]

[154]

[155]

[99,156]

[157]

[158]

[159]

[160]

[161]

[162]

[163]

[164]

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[166]

[167]

[60,168]

[78,168]

[92,168]

[169]

[170]

[98,171]

[172]

[173]

[174]

[175]

[176]

[177]

[178]

[179]

[88,180]

[181]

[182]

[183]

[184]

[185]

[80,186]

[187]

[188]

[189]

[190]

[191]

[192]

[193]

[194]

[72,195]

[196]

[197]

[198]

[199]

[200]

Как мы заметили, есть такие числа, которые не являются суммой делителей ни одного числа и так же есть такие числа, которые являются суммой делителей ни одного, а нескольких чисел. Теперь посмотрим только те числа, которые являются суммой делителей ни одного, а нескольких чисел:

[6,12], [11,12]

[10,18], [17,18]

[14,24], [15,24], [23,24]

[16,31]. [25,31]

[21,32], [31,32]

[20, 42], [26,42], [41,42]

[33,48], [35,48], [47,48]

[34,5 4], [53,54]

[28,56], [39,56]

[24,60], [38,60], [59, 60]

[30,72], [46,72], [51,72], [55,72], [71,72]

[57,80], [79,80]

[44,84], [65,84], [83,84]

[40,90], [58, 9 0], [89,90]

[42,96], [62,96], [69,96], [77,96]

[52,98], [97,98]

[54,120], [56, 120], [87,120], [95,120]

[48,124], [75,124]

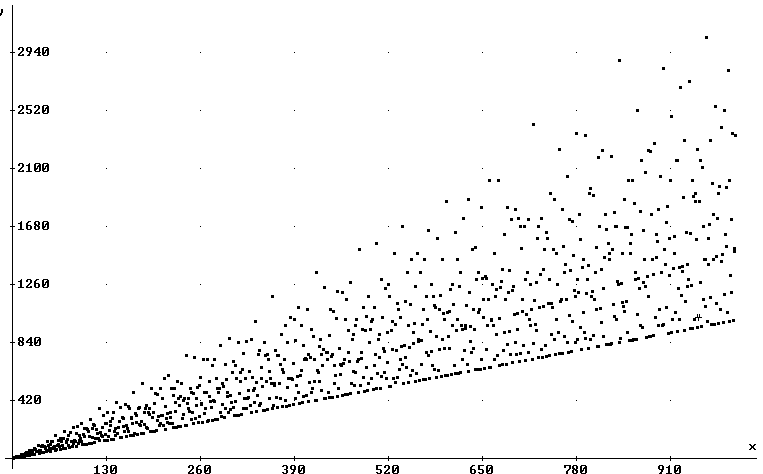
[68,126], [82,126]

[66,144], [70, 144], [94,144]

[60,168], [78,168], [92,168]

Отсюда можно сделать вывод, что нахождение числа по его сумме делителей не всегда возможно и не всегда однозначно.

Теперь построим график. По оси Х расположим числа, а по оси Y их сумму делителей (числа от 1 до 1000):



Посмотрим, что же у нас получилось: на графике отчётливо просматриваются несколько прямых линий, например, нижняя это – простые числа. Верхняя граница – это наиболее сложные числа (имеющие наибольшее количество делителей) - это не прямая, но и не парабола. Скорее всего, – это показательная функция (у = ах).

В мемуарах Эйлера я нашел много интересных мне рассуждений(σ(n) – сумма делителей числа n): Определив значение σ(n) мы ясно видим, что если p – простое, то σ(p)= p + 1. σ(1)=1, а если число n – составное, то σ(n)>1 + n.

Если a, b, c, d – различные простые числа, то мы видим:

σ(ab)=1+a+b+ab=(1+a)(1+b)= σ(a)σ(b)

σ(abcd)= σ(a)σ(b)σ(c)σ(d)

σ(a^2)=1+a+a2=



σ(a^3)=1+a+a2+a3=



И вообще

σ(nn)=



Пользуясь этим:

σ(aqbwcedr)= σ(aq)σ(bw)σ(ce)σ(dr)

Например σ(360), 360 = 23\*32\*5 => σ(23) σ(32) σ(5)=15\*13\*6=1170.

Чтобы показать последовательность сумм делителей приведём таблицу:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***n*** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **0** | - | 1 | 3 | 4 | 7 | 6 | 12 | 8 | 15 | 13 |
| **10** | 18 | 12 | 28 | 14 | 24 | 24 | 31 | 18 | 39 | 20 |
| **20** | 42 | 32 | 36 | 24 | 60 | 31 | 42 | 40 | 56 | 30 |
| **30** | 72 | 32 | 63 | 48 | 54 | 48 | 91 | 38 | 60 | 56 |
| **40** | 90 | 42 | 96 | 44 | 84 | 78 | 72 | 48 | 124 | 57 |
| **50** | 93 | 72 | 98 | 54 | 120 | 72 | 120 | 80 | 90 | 60 |
| **60** | 168 | 62 | 96 | 104 | 127 | 84 | 144 | 68 | 126 | 96 |
| **70** | 144 | 72 | 195 | 74 | 114 | 424 | 140 | 96 | 168 | 80 |
| **80** | 186 | 121 | 126 | 84 | 224 | 108 | 132 | 120 | 180 | 90 |
| **90** | 234 | 112 | 168 | 128 | 144 | 120 | 252 | 98 | 171 | 156 |

Если σ(n) обозначает член любой этой последовательности, а σ(n - 1), σ(n - 2), σ(n - 3)… предшествующие члены, то σ(n) всегда можно получить по нескольким предыдущим членам:

σ(n) = σ(n - 1) + σ(n - 2) - σ(n - 5) - σ(n - 7) + σ(n - 12) + σ(n - 15) - σ(n - 22) - σ(n – 26) + … (\*\*)

Знаки «+» «-» в правой части формулы попарно чередуются. Закон чисел 1, 2, 5, 7, 12, 15…,которые мы должны вычитать из рассматриваемого числа n, станет ясен если мы возьмем их разности:

Числа:1, 2, 5, 7, 12, 15, 22, 26, 35, 40, 51, 57, 70, 77, 92, 100…

Разности: **1**, 3, **2**, 5, **3**, 7, **4**, 9, **5**, 11, **6**, 13, **7**, 15, **8**…

В самом деле, мы имеем здесь поочередно все целые числа 1, 2, 3, 4, 5, 6, 7… и нечетные 3, 5, 7,9 11…

Хотя эта последовательность бесконечна, мы должны в каждом случае брать только те члены, для которых числа стоящие под знаком σ, еще положительны, и опускать σ для отрицательных чисел. Если в нашей формуле встретиться σ(0), то, поскольку его значение само по себе является неопределённым, мы должны подставить вместо σ(0) рассматриваемое число n. Примеры:

σ(1) = σ(0) =1 = 1

σ(2) = σ(1) + σ(0) = 1 + 2 = 3

…

σ(20) = σ(19)+σ(18)-σ(15)-σ(13)+9σ(8)+σ(5)=20+39-24-14+15+6= 42

Доказательство теоремы (\*\*) я приводить не буду.

Вообще, найти сумму всех делителей числа можно с помощью канонического разложения натурального числа (это уже было сказано выше). Сумму делителей числа n обозначают σ(n). Легко найти σ(n) для небольших натуральных чисел, например σ(12) = 1+2+3+4+6+12=28(это было приведено выше). Но при достаточно больших числах отыскивание всех делителей, а тем более их суммы становится затруднительным. Совсем другое дело, если уже известно, что каноническое

разложение числа n таково:.



Его делителями являются все числа , для которых 0 ≤βs ≤ αs, s = 1, …, k. Ясно, что σ(n) представляет собой сумму всех таких чисел при различных значениях показателей



β1, β2, … βk. Этот результат мы получим раскрыв скобки в произведении



По формуле конечного числа членов геометрической прогрессии приходим к равенству

(\*)



По этой формуле σ(360) = .



Формулу для вычисления значения функции σ(n) вывел замечательный английский математик Джон Валлис(1616 - 1703) – один из основателей и первых членов Лондонского Королевства общества (Академии наук). Он был первым из английских математиков, начавших заниматься математическим анализом. Ему принадлежат многие обозначения и термины, применяемые сейчас в математике, в частности знак ∞ для обозначения бесконечности. Валлис вывел удивительную формулу, представляющую число π в виде бесконечного произведения:



Д. Валлис много занимался комбинаторикой и её приложениями к теории шифров, не без основания считая себя родоначальником новой науки – криптологии (от греч. «криптос» - тайный, «логос» - наука, учение). Он был одним из лучших шифровальщиков своего времени и по поручению министра полиции Терло занимался в республиканском правительстве Кромвеля расшифровкой посланий монархических заговорщиков.

С функцией σ(n) связан ряд любопытных задач. Например:

1.) Найти пару целых чисел, удовлетворяющих условию: σ(m1)=m2, σ(m2)=m1.

Некоторые из них не удаётся решить даже с использованием формулы (\*). Так, например, не иначе как подбором можно найти числа, для которых σ(n) есть квадрат некоторого натурального числа. Такими числами являются 22, 66, 70, 81, 343, 1501, 4479865. Вот ещё две задачи, приведённые в 1657 г. Пьером Ферма:

1. найти такое m, для которого σ(m3) – квадрат натурального числа (Ферма нашёл не одно решение этой задачи);
2. найти такое m, для которого σ(m2) – куб натурального числа.

Например, одним из решений первой задачи является m = 7, а для второй m = 43098.

С помощью программы Derive, я попробовал найти ещё решения и у меня этого не получилось. (я рассматривал σ(m3) = n2, где m принимает значения от 1 до 1000, а n от 1 до 5000 в 1.) и тоже самое в 2.) )

Формулы:

1. DELITELI(m) := SELECT(MOD(m, n) = 0, n, 1, m)

DIMENSION(DELITELI(m))

2. SUMMADELITELEY(m) := Σ ELEMENT(DELITELI(m), i)

i=1