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"Solutions of Polynomial Equation of 7th degree using Vedic Method"

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Introduction

The present paper deals with the evaluation of all the 7 solutions of the 7th degree polynomial equation using Vedic sutram and method. The given equation is $\mathbf{x^7 + x^6 - 8x^5 - 6x^4 + 18x^3 + 10x^2 - 9x - 5 = 0}$ and by applying only one method, Swamiji Jagadguru, Shankaracharya's Straight Division method

Abstract

By the application of the principle of Vilokanam, the RHS and LHS parts of the equation are evaluated using different values for "x". A clear indication of locating at least one probable value of the solution could not be suggested from the values of RHS-LHS, as such one had to start with a different variable $x=\frac{z}{10}$.

The Vilokanam method is repeated on the z form of the equation from which one could pick out for the 1st solution S_1 at z=8, the second solution S_2 at z=16, the third solution S_3 at z=-18, the 4th solution S_4 at z=20 and for the 5th solution S_5 at z=-24. With those values, each solution using the five distinct values of "z" being worked out separately and after getting acceptable results, the given equation is written in the form of a product. The given equation is equal to the product and a quadratic equation consisting of the remaining two solutions The quadratic equation can be resolved using Adyamadyena Antyamantyena sutram. All the working details are clearly shown in the respective forms of the expressions and methods.

In all these calculations, 7 decimals are considered for each solution , tables are prepared for all the derivative (representatives as) F'(z), F"(z), F'"(z), F^{iv}(z0, F^{v}(z), F^{vi}(z) at z=8,16,-18,-20,-24. F' being the Common Divisor. The solutions are in the form of a.bcdefgh, the expansion of 7 decimals are considered (b$\rightarrow$h) while "a" is he integer part of each solution. The straight division method is adopted for each of the five solutions 1 to 5 while the two final solutions are read by solving a quadratic equation. Working details are clearly presented in the text for all the 7 solutions. All the solutions are real out of which 3 are +ve and 4 are –ve. They lie between 0.6 and 2.4

Let us consider the 7th order Equation $\mathbf{E = x^7 + x^6 - 8x^5 - 6x^4 + 18x^3 + 10x^2 - 9x - 5 = 0}$

The RHS-LHS values are determined for different values of "x" shown in Table – 1.

Table - 1

Value of x	L.H.S	R.H.S	Diff
1	7	5	– 2
2	6	5	– 1
3	1035		– 1030
0	0		5

– 1	3	2
– 2	10	– 5
– 3	– 369	374

The solutions probably may lie between (1, 2), (– 2, –1) (– 3, –2) and (0, 1) but there is no clear indication and hence we chose a different variable as $x=\frac{z}{10}$

$$\text{Let } x = \frac{z}{10} \Rightarrow \frac{z^7}{10^7} + \frac{z^6}{10^6} - \frac{8z^5}{10^5} - \frac{6z^4}{10^4} + \frac{18z^3}{10^3} + \frac{10z^2}{10^2} - \frac{9z}{10} = 5$$

$$z^7 + 10z^6 - 800z^5 - 6000z^4 + 180000z^3 + 1000000z^2 - 9000000z = 5 \times 10^7$$

Here the value of “z” is ranged from z=8.

Table - 2

	Value of z	L.H.S	R.H.S	Difference
	7	21888433		
1	8	38088192		11911808
	9	54712179		– 4712179
	10	70000000		
	15	71015625		
2	16	53410816		– 3410816
	17	35042763		– 14957237
	18	22591872		
4	19	26145349		23854651
	20	60000000		– 10000000
	– 17	23456617		
3	– 18	45940608		4059392
	– 19	72920271		– 22920271
	– 20	1×10^8		
	– 21	119987469		
	– 22	122170752		
5	– 23	91501843		– 41501843
	– 24	7681536		42318464

The 5 values for the z are selected as S_1=8, S_2=16, S_3=-18, S_4=20, S_5=-24, approximately x_1=0.8, x_2=1.6, x_3=-1.8, x_4=2.0, x_5=-2.4

$$F(x)=x^7 + x^6 - 8x^5 - 6x^4 + 18x^3 + 10x^2 - 9x - 5 = 0$$

The given equation is represented in the terms of "z" as $x = \frac{z}{10}$

$\Rightarrow F(z) = z^7 + 10z^6 – 800z^5 – 6000z^4 + 180000z^3 + 1000000z^2 – 9000000z = 5 \times 10^7$

The working details for each solution with its $x=\frac{z}{10}$ of the corresponding equation in "z" has to be evaluated separately. Similarly considering the general expansion $(a+b+c+d+e+f+g+h)^7$ has to be considered and the corresponding terms which will be the different representatives of the polynomial equation have to be sorted out. T hey will be subtracted from the respective dividends, corresponding to the positions of the decimals b→h. After the subtraction, each result is divided by the CD to get the respective decimal as quotients and reminders which is to be added to the next dividend to form the new dividend. This procedure is continued until all the decimals from b to h are evaluated.

With z=8 :

i) CD Representation at z = 8 = $(7z^6 + 60z^5 – 4000z^4 – 24000z^3 + 540000z^2 + 2 \times 10^6 z – 9 \times 10^6)$ at z = 8 = 16689088

ii) $21a^5$ Representation at z = 8 = $\frac{1}{2}(42z^5 + 300z^4 – 16000z^3 – 72000z^2 + 1080000z + 2 \times 10^6)$ at z = 8 = 222528

iii) $35a^4$ Representation at z = 8 = $\frac{1}{6}(210z^4 + 1200z^3 – 48000z^2 – 144000z + 1080000)$ at z = 8 = – 278240

iv) $35a^3$ Representation at z = 8 = $\frac{1}{24}(840z^3 + 3600z^2 – 96000z – 144000)$ at z = 8 = – 10480

v) $21a^2$ Representation at z = 8 = $\frac{1}{120}(2520z^2 + 7200z – 96000)$ at z = 8 = 1024

vi) 7a Representation at z = 8 = $\frac{1}{720}(5040z + 7200)$ at z = 8 = 66

Table – 3

CD = 16689088	0 11911808	0 2294464	0 12040768	0 15574944	0 10014512	0 14776160	0 7340510
		$\overline{10903872}$	95436320 – 0=95436320	0+25162480 – 37384704+0 = $\overline{12222224}$	–24923136+0 – 17210368+ 490815360 +0+0=448681856	–7764834– 32044032 –99692544+0 + 327210240 +172542720 =360251550	–823543+0–147517440 +0+115028480+0 +0+1308840960+0 +841397760+0 –93461760– 42725376 = 1980739081
		$–(21a^5b^2)$	$–(35a^4b^3 +21a^5 2bc)$	$–(21a^5c+35a^3b^4 + 21a^5.2bd+35a^4.3b^2c)$	$–(21a^2b^5+21a^5.2be +21a^5.2cd+35a^4 3b^2d +35a^4.3bc^2+35a^3 .4b^3c)$	$–(7ab^6+21a^5d^2 +21a^5.2bf +21a^5.2ce+35a^4c^3 +35a^4.3b^2e+35a^4.6bcd +35a^3.4b^3d+35a^3.6b^2c^2 +21a^2.5b^4c)$	$–(b^7+7a.6b^5c +21a^2.5b^4d+21a^2.10b^3c^2 +35a^3 4b^3e+35a^3.12b^2cd +35a^3.4bc^3+35a^4.3b^2f +35a^4.6bce+35a^4.3bd^2 +35a^4.3c^2d+21a^5.2bg +21a^5.2cf +21a^5.2de)$
8. a	7 b	0 c	12 d	8 e	32 f	30 g	123 h

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1) The first decimal b is obtained as a coefficient by considering the first ID as ND and the same is divided by CD

2) The successive decimal values are to be obtained in the usual manner, ie ND ÷ CD where ND = ID – corresponding subtraction terms

3) Values of subtraction terms containing $7a^6$, $21a^5$, $31a^4$, $35a^3$, $21a^2$ and 7a are to be worked out in terms of representation values.

Upto h (7 decimals) z = 8. 7 0 12 8 32 30 123 = 8. 7 1 3 1 6 23 $x = \frac{z}{10}$ = 0.87131623 (x_1)

E = – 0.000003673141

The deduction terms are from the general expansion of $(a+b+c+d+e+f+g)^7$

With z=16 :

CD Representation at z = 16 = $(7z^6 + 60z^5 – 4000z^4 – 24000z^3 + 540000z^2 + 2 \times 10^6 z – 9 \times 10^6)$ at z = 16 = – 18852928

$21a^5$ Representation at z = 16 = $\frac{1}{2}(42z^5 + 300z^4 – 16000z^3 – 72000z^2 + 1080000z + 2 \times 10^6)$ at z = 16 = – 493504

$35a^4$ Representation at z = 16 = $\frac{1}{6}(210z^4 + 1200z^3 – 48000z^2 – 144000z + 1080000)$ at z = 16 = 860960

$35a^3$ Representation at z = 16 = $\frac{1}{24}(840z^3 + 3600z^2 – 96000z – 144000)$ at z = 16 = 111760

$21a^2$ Representation at z = 16 = $\frac{1}{120}(2520z^2 + 7200z – 96000)$ at z = 16 = 5536

7a Representation at z = 16 = $\frac{1}{720}(5040z + 7200)$ at z = 16 = 122

Table – 4

CD = 18852928	0 3410816	0 15255	0 1235392	0 5318816	0 4672848	0 6258432	0 16020730
		493504	–860960 +7896064 =7035104	31584256 – 111760– 20663040 =10809456	– 5536+1974016+0+0 – 165304320– 3576320 = – 166912160	–122+0+010857088 +15792128– 440811520–5165760 +0–42915840–221440 = – 462465466	–1–5856+0–3543040 – 894080+0–228884480 –28411680–82652160 +0+26649216+86856704 = –230885377
		$–(21a^5b^2)$	$–(35a^4b^3 +21a^5 2bc)$	$–(21a^5c^2+35a^3b^4 + 21a^5.2bd+35a^4.3b^2c)$	$–(21a^2b^5+21a^5.2be +21a^5.2cd+35a^4 3b^2d +35a^4.3bc^2+35a^3.4b^3c)$	$–(7ab^6+21a^5d^2 +21a^5.2bf +21a^5.2ce+35a^4c^3 +35a^4.3b^2e+35a^4.6bcd +35a^3.4b^3d+35a^3.6b^2c^2 +21a^2.5b^4c)$	$–(b^7+7a.6b^5c +21a^2.5b^4d+21a^2.10b^3c^2 +35a^3 4b^3e+35a^3.12b^2cd +35a^3.4bc^3+35a^4.3b^2f +35a^4.6bce+35a^4.3bd^2 +35a^4.3c^2d+21a^5.2bg +21a^5.2cf +21a^5.2de)$
16 a	1 b	8 c	0 d	2 e	11 f	27 g	20 H

1) The first decimal b is obtained as a coefficient by considering the first ID as ND and the same is divided by CD

2) The successive decimal values are to be obtained in the usual manner, ie ND ÷ CD where ND = ID – corresponding subtraction terms

3) Values of subtraction terms containing $7a^6$, $21a^5$, $31a^4$, $35a^3$, $21a^2$ and 7a are to be worked out in terms of representation values.

Upto h (7 decimals) z = 16. 1 8 0 2 11 27 20 = 16. 1 8 0 3 3 9 0 $\Rightarrow x = \frac{z}{10} = 1.61803390\ (x_2)$

E = 0.000001681302

With z=-18 :

CD Representation at z = – 18 = $(7z^6 + 60z^5 - 4000z^4 - 24000z^3 + 540000z^2 + 2 \times 10^6 z - 9 \times 10^6)$ z = – 18 = – 25264512

$21a^5$ Representation at z = – 18 = $\frac{1}{2}(42z^5 + 300z^4 - 16000z^3 - 72000z^2 + 1080000z + 2 \times 10^6)$ z = – 18 = 2337472

$35a^4$ Representation at z = – 18 = $\frac{1}{6}(210z^4 + 1200z^3 - 48000z^2 - 144000z + 1080000)$ z = – 18 = 527760

$35a^3$ Representation at z = –18 = $\frac{1}{24}(840z^3 + 3600z^2 - 96000z - 144000)$ z = – 18 = – 89520

$21a^2$ Representation at z = – 18 = $\frac{1}{120}(2520z^2 + 7200z - 96000)$ z = – 18 = 4924

7a Representation at z = – 18 = $\frac{1}{720}(5040z + 7200)$ z = – 18 = – 116

Table – 5

CD = –25264512	0 4059392	0 15329408	0 24634048	0 21377424	0 24885760	0 21410092	0 20773304
		– 2337472	527760 – 23374720 = –22846960	–58436800 – 37399552+89520 +7916400 = – 8783.432	4924–18699776 – 186997760+12666240 +39582000+1790400 = – 151653972	116–149598208 – 14024832–93498880 +65970000+6333120 +126662400+2864640 +13428000+123100 =–41740544	1+3480+196960 +1231000+1432320 +42969600+44760000 +4749840+63331200 +101329920+316656000 –28049664–70124160 – 149598208=328888289
		$-(21a^5b^2)$	$-(35a^4b^3 +21a^5 2bc)$	$-(21a^5c^2+35a^3b^4 + 21a^5.2bd+35a^4.3b^2c)$	$-(21a^2b^5+21a^5.2be +21a^5.2cd+35a^4 3b^2d +35a^4.3bc^2+35a^3.4b^3c)$	$-(7ab^6+21a^5d^2 +21a^5.2bf +21a^5.2ce+35a^4c^3 +35a^4.3b^2e+35a^4.6bcd +35a^3.4b^3d+35a^3.6b^2c^2 +21a^2.5b^4c)$	$-(b^7+7a.6b^5c +21a^2.5b^4d+21a^2.10b^3c^2 +35a^3 4b^3e+35a^3.12b^2cd +35a^3.4bc^3+35a^4.3b^2f +35a^4.6bce+35a^4.3bd^2 +35a^4.3c^2d+21a^5.2bg +21a^5.2cf +21a^5.2de)$
– 18 a	$\bar{1}$ b	$\bar{5}$ c	$\bar{8}$ d	$\bar{4}$ e	$\bar{3}$ f	$\bar{6}$ g	$\overline{21}$ h

1) The first decimal b is obtained as a coefficient by considering the first ID as ND and the same is divided by CD

2) The successive decimal values are to be obtained in the usual manner, ie ND ÷ CD where ND = ID – corresponding subtraction terms

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3) Values of subtraction terms containing $7a^6$, $21a^5$, $31a^4$, $35a^3$, $21a^2$ and 7a are to be worked out in terms of representation values.

Upto h (7 decimals) $z = -18.\bar{1}\ \bar{5}\ \bar{8}\ \bar{4}\ \bar{3}\ \bar{6}\ \overline{21} = \overline{18}.\bar{1}\ \bar{5}\ \bar{8}\ \bar{4}\ \bar{3}\ \bar{8}\ \bar{1} = -18.1584381$

$\Rightarrow x = \frac{z}{10} = -1.81584381\ (x_3)$ $\qquad$ $E = -0.000000994079$

With z=20 :

CD Representation at z = 20 = $(7z^6 + 60z^5 - 4000z^4 - 2400z^3 + 540000z^2 + 2 \times 10^6 z - 9 \times 10^6) = 55000000$

$21a^5$ Representation at z = 20 = $\frac{1}{2}(42z^5 + 300z^4 - 16000z^3 - 72000z^2 + 1080000z + 2 \times 10^6) = 24600000$

$35a^4$ Representation at z = 20 = $\frac{1}{6}(210z^4 + 1200z^3 - 48000z^2 - 144000z + 1080000) = 3700000$

$35a^3$ Representation at z = 20 = $\frac{1}{24}(840z^3 + 3600z^2 - 96000z - 144000) = 254000$

$21a^2$ Representation at z = 20 = $\frac{1}{120}(2520z^2 + 7200z - 9600) = 8800$

7a Representation at z = 20 = $\frac{1}{720}(5040z + 7200) = 150$

Table – 6

CD = 55000000	0 $\overline{10000000}$	0 $\overline{45000000}$	0 $\overline{34600000}$	0 $\overline{20900000}$	0 $\overline{24454000}$	0 $\overline{36159200}$	0 $\overline{15984150}$
		– 24600000	3700000 – 393600000 = $\overline{389900000}$	–1574400000–639600000–254000+ 88800000 = – 2125454000	8800–2066400000 –5116800000 +144300000 +710400000 –8128000 = – 6336619200	–150–4157400000–5854800000–16531200000 +1894400000+466200000 +2308800000–13208000 – 97536000+352000 = – 2.1984392	1–7200+572000 +5632000–42672000–316992000–520192000 +1320900000 +7459200000 +1875900000 +9235200000–19975200000 –46838400000–26863200000 = –74659259200
		– $(21a^5b^2)$	– $(35a^4b^3 + 21a^5 2bc)$	– $(21a^5c^2+35a^3b^4 + 21a^5.2bd\ 35a^4.3b^2c)$	– $(21a^2b^5 + 21a^5.2bc + 21a^5.2cd+35a^4 3b^2d + 35a^4.3bc^2 + 35a^3.4b^3c)$	– $(7ab^6+21a^5d^2 + 21a^5.2bf + 21a^5.2ce+35a^4c^3 + 35a^4.3b^2e+35a^4.6bcd + 35a^3.4b^3d+35a^3.6b^2c^2 + 21a^2.5b^4c)$	– $(b^7+7a.6b^5c + 21a^2.5b^4d+21a^2.10b^3c^2 + 35a^3 4b^3e+35a^3.12b^2cd + 35a^3.4bc^3+35a^4.3b^2f + 35a^4.6bce+35a^4.3bd^2 + 35a^4.3c^2d+21a^5.2bg + 21a^5.2cf + 21a^5.2de)$
20 a	$\bar{1}$ b	$\bar{8}$ c	$\overline{13}$ d	$\overline{42}$ e	$\overline{119}$ f	$\overline{406}$ g	$\overline{1360}$ h

1) The first decimal b is obtained as a coefficient by considering the first ID as ND and the same is divided by CD

2) The successive decimal values are to be obtained in the usual manner, ie ND ÷ CD where ND = ID – corresponding subtraction terms

3) Values of subtraction terms containing $7a^6$, $21a^5$, $31a^4$, $35a^3$, $21a^2$ and 7a are to be worked out in terms of representation values.

Upto h (7 decimals) $z = 20.\ \overline{1}\ \overline{8}\ \overline{13}\ \overline{42}\ \overline{119}\ \overline{406}\ \overline{1360} = 20.\ \overline{1}\ \overline{9}\ \overline{8}\ \overline{9}\ \overline{3}\ \overline{2}\ \overline{0} = 19.8010680$

$\Rightarrow x = \frac{z}{10} = 1.98010680\ (x_4)$ E=0.000352565993

With z=-24 :

CD Representation at $z = -24 = (7z^6 + 60z^5 - 4000z^4 - 24000z^3 + 540000z^2 + 2 \times 10^6 z - 9 \times 10^6)$ at $z = -24 = 18675392$

$21a^5$ Representation at $z = -24 = \frac{1}{2}(42z^5 + 300z^4 - 16000z^3 - 72000z^2 + 1080000z + 2 \times 10^6)$ at $z = -24 = -39552704$

$35a^4$ Representation at $z = -24 = \frac{1}{6}(210z^4 + 1200z^3 - 48000z^2 - 144000z + 1080000)$ at $z = -24 = 4995360$

$35a^3$ Representation at $z = -24 = \frac{1}{24}(840z^3 + 3600z^2 - 96000z - 144000)$ at $z = -24 = -307440$

$21a^2$ Representation at $z = -24 = \frac{1}{120}(2520z^2 + 7200z - 96000)$at $z = -24 = 9856$

7a Representation at $z = -24 = \frac{1}{720}(5040z + 7200)$ at $z = -24 = -158$

Table – 7

CD = 118675392	0 42318464	0 67158464	0 78155840	0 53030240	0 108048304	0 21069380	0 93810454
		35597433 6	1898529792– 134874720 = 1763655072	2531373056 +4983640704 +24902640 – 1078997760 = 6460918640	– 2395008 +13764340992 +13289708544 – 2832369120 – 2877327360 +265628160 =21607586210	115182 +45327398780 +36704909310+1 7442742460 – 2557624320– 7822733760– 15105968640 +697273920 +1062512640 – 3193340 = 75716692140	–2187+1842912– 83825280–170311680 +1625804160 +5578191360 +1888911360– 25761071520– 41721246720– 19826583840– 20141291520 +151645067100+120873 063400 +96350386940 =270558934500
		– $(21a^5b^2)$	– $(35a^4b^3 + 21a^5 2bc)$	– $(21a^5c^2+35a^3b^4 +$ $21a^5.2be\ 35a^4.3b^2c)$	– $(21a^2b^5 +21a^5.2bc$ $+21a^5.2cd+35a^4 3b^2d$ $+35a^4.3bc^2 +35a^3.4b^3c)$	– $(7ab^6+21a^5d^2$ $+21a^5.2bf$ $+21a^5.2ce+35a^4c^3$ $+35a^4.3b^2e+35a^4.$ $6bcd$ $+35a^3.4b^3d+35a^3.$ $6b^2c^2 +21a^2.5b^4c)$	– $(b^7+7a.6b^5c +21a^2.5b^4d$ $+21a^2.10b^3c^2 +35a^3 4b^3e$ $+35a^3.12b^2cd +35a^3.4bc^3$ $+35a^4.3b^2f +35a^4.6bce$ $+35a^4.3bd^2$ $+35a^4.3c^2d+21a^5.2bg$ $+21a^5.2cf +21a^5.2de)$
– 24 a	3 b	8 c	21 d	58 e	191 f	639 g	2287 H

1) The first decimal b is obtained as a coefficient by considering the first ID as ND and the same is divided by CD

2) The successive decimal values are to be obtained in the usual manner, ie ND ÷ CD where ND = ID – corresponding subtraction terms

3) Values of subtraction terms containing $7a^6$, $21a^5$, $31a^4$, $35a^3$, $21a^2$ and 7a are to be worked out in terms of representation values.

Upto h (7 decimals) z = – 24. 3 8 21 58 191 639 2287 = – 24. 4 0 9 5 7 7 7 = $\overline{23.5904223}$ = – 23.5904223 $\Rightarrow x = \frac{z}{10}$ = – 2.35904223 (x_5), E=-0.001210641110

∴E=(x – 0.87131623), (x – 1.61803390), (x + 1.81584381), (x – 1.98010680), (x + 2.35904223) A are the factors of E

Where A = $(x^2 + \alpha x + \beta)$, α and β are to be determined.

Applying Adyamadyena Antyamantyena and Argumentation A = $(x^2 + \alpha x + 0.418122717)$

$E = (x^5 – 0.29457089x^4 - 8.03682279x^3 + 4.52740386x^2 +15.49948340x - 11.95821179) (x^2 + \alpha x + 0.418122717)$

Comparing x coefficient on both sides

α = 1.294565306

∴ A = $(x^2 + 1.294565306x + 0.418122717)$

A is to be further factorised using differential relation

$2x + 1.294565306 = \pm\sqrt{1.675899332 - 1.672490868} = \pm\sqrt{0.003408464} = \pm 0.058382052$

x = – 0.676473679, – 0.618091627 (x_6 & x_7

∴ E =(x – 0.87131623) (x – 1.61803390) (x + 1.81584381) (x – 1.98010680) (x + 2.35904223) (x + 0.676473679) (x + 0.618091627)

Applying Gunita Samuchayya

S_c= 2 = (0.128584)(–0.61803390)(2.81584381)(–0.98010680)(3.35904223)(1.676473679)(1.618091627) =2.000015~2

Table – 8

Expansion Table

$(a+b+c+d+e+f+g+h)^7$

	1	7	21	35	42	105	140	210	420
10^0	a^7								
10^1		a^6b							
10^2		a^6c	a^5b^2						
10^3		a^6d		a^4b^3	a^5bc				
10^4		a^6e	a^5c^2	a^3b^4	a^5bd	a^4b^2c			
10^5		a^6f	a^2b^5		a^5be a^5cd	a^4b^2d a^4c^2b	a^3b^3c		

10^6		ab^6 a^6g	a^5d^2	a^4c^3	a^5bf, a^5ce	a^4b^2c, a^2b^4c	a^3b^3d	$a^3b^2c^2$ a^4bcd	
10^7	b^7	a^6h			a^5bg, a^5cf, a^5de ab^5c	a^4b^2f a^4c^2d a^4d^2b a^2b^4d	a^3b^3e a^3c^3b	$a^2b^3c^2$ a^4bce	a^3b^2cd
10^8		a^6i b^6c	a^5e^2	a^3c^4	a^5bh a^5cg, a^5df ab^5d	a^4b^2g a^4c^2e a^4d^2c a^2b^4e ab^4c^2	a^3b^3f	$a^3b^2d^2$ a^4bcf a^4bde $a^2b^2c^3$	a^3b^2ce a^2b^3cd a^3bc^2d

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