Ada Lovelace's Computer Program

Apple Time

Elsa Gonsiorowski

June 23, 2023

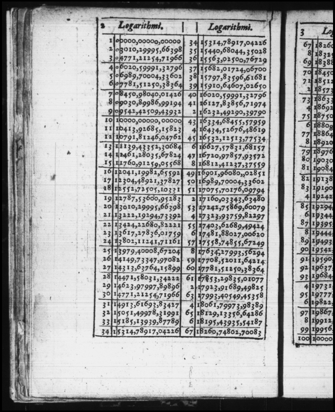
Apple Time

15 Min	Short Talk
15 Min	Breakout 1
15 Min	Breakout 2
10 Min	Prizes!

Elsa Gonsiorowski

- HPC I/O Support Specialist in Livermore Computing since 2016
- Develop SCR: Scalable Checkpoint Restart library
- LC Hotline tech
- Excited about emacs, org-mode, static websites, fish shell, cmake, documentation, crossfit, rowing, knitting

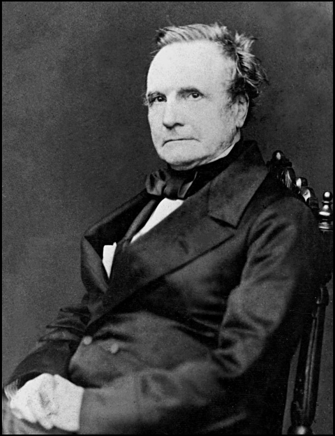
Mathematical Tables



2	Logarithmi.		Logarithmi.
1	00000,00000,00000	34	15314,78917,04226
2	03010,29995,66398	35	15440,68044,35028
3	04771,21254,71966	36	15563,02500,76729
4	06020,59991,32796	37	15682,01724,06700
5	06989,70004,33602	38	15797,83596,61681
6	07781,51250,38364	39	15910,64607,02650
7	08450,98040,01426	40	16020,59991,32796
8	09030,89986,99194	41	16127,83856,71974
9	09542,42509,43932	2	16232,49290,39790
10	10000,00000,00000	43	16334,68455,57959
11	10413,92685,15823	4	16434,52676,48619
12	10791,81246,04762	45	16532,12513,77534
13	11139,43352,30684	6	16627,57831,68157
14	11461,28035,67824	47	16720,97857,93572
15	11760,91259,05568	8	16812,41237,37559
16	12041,19982,65592	49	16901,96080,,02851
17	12304,48921,37827	50	16989,70004,33602
18	12552,72505,10331	51	17075,70176,09794
19	12787,53600,95283	2	17160,03343,63480
20	13010,29995,66398	53	17242,75869,60079
21	13222,19294,73392	4	17323,93759,82297
22	13424,22680,82221	55	17403,62689,49424
23	13617,27836,01759	6	17481,88027,00620
24	13802,11241,71161	57	17558,74855,67249
25	13979,40008,67204	8	17634,27993,56294
26	14149,73347,97082	59	17708,52011,64214
27	14313,63764,15899	60	17781,51250,38364
28	14471,58031,34222	61	17853,29835,01077
29	14623,97997,89896	2	17923,91689,49825
30	14771,21254,71966	63	17993,40549,45358
31	14913,61693,83427	4	18061,79973,98389
32	15051,49978,31991	65	18129,13356,64286
33	15185,13939,87789	6	18195,43935,54187
34	15314,78917,04226	67	18260,74802,70083

- Calculated values of logarithmic and trigonometric functions
- Built by hand by human "computers"
- Used to do rapid multiplication, division, and exponentiation

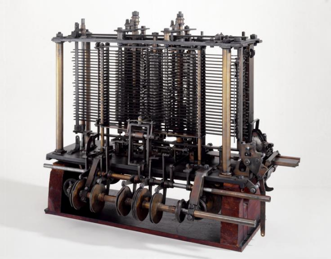
Charles Babbage and the Difference Engine



- 1791–1871
- Idea for a *Difference Engine* to mechanically do the work of human computers
  - Began development in 1822
  - would have composed 25,000 parts, weighed 15 tons, stood 8 feet tall

Analytical Engine

- Design began in 1833, described in 1837
- General purpose, i.e., Turing Complete
- Arithmetic logic unit, control flow (conditional branching and loops), memory, printer, and bell

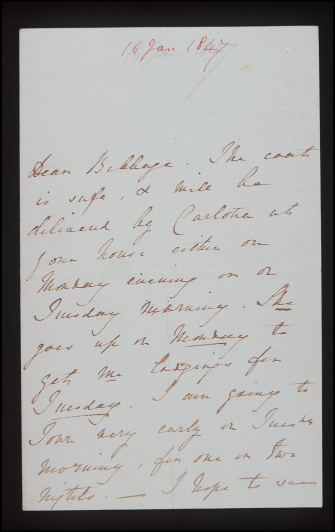


Augusta Ada King (née Byron), Countess of Lovelace

- Dec. 10, 1815–Nov. 27, 1852
- Child of poet Lord Byron and Lady Byron
- 1833: Met Charles Babbage at a party
- 1835: Married William King who became Earl of Lovelace

Babbage and Young Lady Byron

- 1833: Met at a party (Babbage age 41, Ada age 17)
- Ada had extensive mathematics eduction to "ward off wild, romatic sensibility" of her father
- They were in the same social circle and wrote each other frequently



16 Jan 1847

Dear Babbage. The coat is safe, & will be delivered by Carlotta at your house either on Monday evening or on Tuesday morning. She goes up on Monday to get me lodgings for Tuesday. I am going to Town very early on Tuesday morning, for one or two nights. — I hope to see

Sketch of the Analytical Engine

SCIENTIFIC MEMOIRS,

SELECTED FROM

THE TRANSACTIONS OF

FOREIGN ACADEMIES OF SCIENCE

AND LEARNED SOCIETIES,

AND FROM

FOREIGN JOURNALS.

EDITED BY

RICHARD TAYLOR, F.S.A.,

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VOL. III.

LONDON:

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.

SOLD BY LONGMAN, ORME, BROWN, GREEN, AND LONGMANS; CADELL; RIDGWAY AND SONS; SHERWOOD, GILBERT, AND PIPER; SIMPKIN AND MARSHALL; B. FELLOWES; S. HIGHLEY; WHITTAKER AND CO.; AND J. B. BAILLIERE, LONDON:—AND BY A. AND C. BLACK, AND THOMAS CLARK, EDINBURGH; SMITH AND SON, GLASGOW:—MILLIKEN AND SON, AND HODGES AND M'ARTHUR, DUBLIN:—DOBSON, PHILADELPHIA:—AND GOODHUGH, NEW YORK.

1843.

ARTICLE XXIX.

Sketch of the Analytical Engine invented by Charles Babbage *Esq. By* L. F. MENABREA, *of Turin, Officer of the Military Engineers.*

[From the *Bibliothèque Universelle de Génève*, No. 82. October 1842.]

[BEFORE submitting to our readers the translation of M. Menabrea's memoir 'On the Mathematical Principles of the ANALYTICAL ENGINE' invented by Mr. Babbage, we shall present to them a list of the printed papers connected with the subject, and also of those relating to the Difference Engine by which it was preceded.

For information on Mr. Babbage's "*Difference* Engine," which is but slightly alluded to by M. Menabrea, we refer the reader to the following sources:—

1. Letter to Sir Humphry Davy, Bart., P.R.S., on the Application of Machinery to Calculate and Print Mathematical Tables. By Charles Babbage, Esq., F.R.S. London, July 1822. Reprinted, with a Report of the Council of the Royal Society, by order of the House of Commons, May 1823.

2. On the Application of Machinery to the Calculation of Astronomical and Mathematical Tables. By Charles Babbage, Esq.—Memoirs of the Astronomical Society, vol. i. part 2. London, 1822.

3. Address to the Astronomical Society by Henry Thomas Colebrooke, Esq., F.R.S., President, on presenting the first Gold Medal of the Society to Charles Babbage, Esq., for the invention of the Calculating Engine.—Memoirs of the Astronomical Society. London, 1822.

4. On the Determination of the General Term of a New Class of Infinite Series. By Charles Babbage, Esq.—Transactions of the Cambridge Philosophical Society.

5. On Mr. Babbage's New Machine for Calculating and Printing Mathematical Tables.—Letter from Francis Baily, Esq., F.R.S., to M. Schumacher. No. 46, Astronomische Nachrichten. Reprinted in the Philosophical Magazine, May 1824.

6. On a Method of expressing by Signs the Action of Ma-

Bernoulli Numbers

$$\sum n = \frac{1}{2}n^2 + \frac{1}{2}n$$

$$\sum n^2 = \frac{1}{3}n^3 + \frac{1}{2}n^2 + \frac{1}{6}n$$

$$\sum n^3 = \frac{1}{4}n^4 + \frac{1}{2}n^3 + \frac{1}{4}n^2$$

$$\sum n^m = \frac{1}{m+1}\left(B_0 n^{m+1} \pm \binom{m+1}{1} B_1 n^m + \binom{m+1}{2} B_2 n^{m-1} + ...\right)$$

$B_7 = -1(A_0 + B_1 A_1 + B_3 A_3 + B_5 A_5)$

$$
\begin{aligned}
A_0 &= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} \\
A_1 &= \frac{2n}{2} \\
A_3 &= \frac{2n(2n-1)(2n-2)}{2 \cdot 3 \cdot 4} \\
A_5 &= \frac{2n(2n-1)(2n-2)(2n-3)(2n-4)}{2 \cdot 3 \cdot 4 \cdot 5 \cdot 6}
\end{aligned}
$$

Notes from the Translator

Note A Promise of a machine that can perform arbirtary mathematical operations

Note G *Lady Lovelace's Objection* – despite it's power, the machine does not "think"

Note D "Diagram of development" for calculating B_7 = -1(A_0 + B_1 A_1 + B_3 A_3 + B_5 A_5)

Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

Number of Operation.	Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data.			Working Variables.										Result Variables.			
						$^1V_1$ ◯ 0 0 0 1	$^1V_2$ ◯ 0 0 0 2	$^1V_3$ ◯ 0 0 0 4	$^0V_4$ ◯ 0 0 0 0	$^0V_5$ ◯ 0 0 0 0	$^0V_6$ ◯ 0 0 0 0	$^0V_7$ ◯ 0 0 0 0	$^0V_8$ ◯ 0 0 0 0	$^0V_9$ ◯ 0 0 0 0	$^0V_{10}$ ◯ 0 0 0 0	$^0V_{11}$ ◯ 0 0 0	$^0V_{12}$ ◯ 0 0 0	$^0V_{13}$ .... ◯ 0 0 0	$^1V_{21}$ ◯ B_1 in a decimal fraction.	$^1V_{22}$ ◯ B_3 in a decimal fraction.	$^1V_{23}$ ◯ B_5 in a decimal fraction.	$^0V_{24}$... ◯ 0 0 0
						1	2	n											B_1	B_3	B_5	B_7
1	×	$^1V_2 \times {}^1V_3$	$^1V_4, {}^1V_5, {}^1V_6$	$\left\{\begin{matrix}^1V_2 = {}^1V_2 \\ ^1V_3 = {}^1V_3\end{matrix}\right\}$	$= 2n$	...	2	n	$2n$	$2n$	$2n$											
2	−	$^1V_4 - {}^1V_1$	$^2V_4$	$\left\{\begin{matrix}^1V_4 = {}^2V_4 \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n - 1$	1	...	...	$2n-1$													
3	+	$^1V_5 + {}^1V_1$	$^2V_5$	$\left\{\begin{matrix}^1V_5 = {}^2V_5 \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n + 1$	1	...	...	...	$2n+1$												
4	÷	$^2V_5 \div {}^2V_4$	$^1V_{11}$	$\left\{\begin{matrix}^2V_5 = {}^0V_5 \\ ^2V_4 = {}^0V_4\end{matrix}\right\}$	$= \frac{2n-1}{2n+1}$	...	...	...	0	0	...	...	...	...	...	$\frac{2n-1}{2n+1}$						
5	÷	$^1V_{11} \div {}^1V_2$	$^2V_{11}$	$\left\{\begin{matrix}^1V_{11} = {}^2V_{11} \\ ^1V_2 = {}^1V_2\end{matrix}\right\}$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$	...	2	...	...	...	...	...	...	...	...	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	−	$^0V_{13} - {}^2V_{11}$	$^1V_{13}$	$\left\{\begin{matrix}^2V_{11} = {}^0V_{11} \\ ^0V_{13} = {}^1V_{13}\end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$	...	...	...	...	...	...	...	...	...	...	0	....	$-\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	−	$^1V_3 - {}^1V_1$	$^1V_{10}$	$\left\{\begin{matrix}^1V_3 = {}^1V_3 \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= n - 1 (= 3)$	1	...	n	...	...	...	...	...	...	$n-1$							
8	+	$^1V_2 + {}^0V_7$	$^1V_7$	$\left\{\begin{matrix}^1V_2 = {}^1V_2 \\ ^0V_7 = {}^1V_7\end{matrix}\right\}$	$= 2 + 0 = 2$	...	2	...	...	...	...	2										
9	÷	$^1V_6 \div {}^1V_7$	$^3V_{11}$	$\left\{\begin{matrix}^1V_6 = {}^1V_6 \\ ^0V_{11} = {}^3V_{11}\end{matrix}\right\}$	$= \frac{2n}{2} = A_1$	...	...	...	...	...	$2n$	2	...	...	...	$\frac{2n}{2} = A_1$						
10	×	$^1V_{21} \times {}^3V_{11}$	$^1V_{12}$	$\left\{\begin{matrix}^1V_{21} = {}^1V_{21} \\ ^3V_{11} = {}^3V_{11}\end{matrix}\right\}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$	...	...	...	...	...	...	...	...	...	...	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	....	B_1			
11	+	$^1V_{12} + {}^1V_{13}$	$^2V_{13}$	$\left\{\begin{matrix}^1V_{12} = {}^0V_{12} \\ ^1V_{13} = {}^2V_{13}\end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$ ...	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	−	$^1V_{10} - {}^1V_1$	$^2V_{10}$	$\left\{\begin{matrix}^1V_{10} = {}^2V_{10} \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= n - 2 (= 2)$	1	...	...	...	...	...	...	...	...	$n-2$							
13	−	$^1V_6 - {}^1V_1$	$^2V_6$	$\left\{\begin{matrix}^1V_6 = {}^2V_6 \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n - 1$	1	...	...	...	...	$2n-1$											
14	+	$^1V_1 + {}^1V_7$	$^2V_7$	$\left\{\begin{matrix}^1V_1 = {}^1V_1 \\ ^1V_7 = {}^2V_7\end{matrix}\right\}$	$= 2 + 1 = 3$	1	...	...	...	...	...	3										
15	÷	$^2V_6 \div {}^2V_7$	$^1V_8$	$\left\{\begin{matrix}^2V_6 = {}^2V_6 \\ ^2V_7 = {}^2V_7\end{matrix}\right\}$	$= \frac{2n-1}{3}$	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$									
16	×	$^1V_8 \times {}^3V_{11}$	$^4V_{11}$	$\left\{\begin{matrix}^1V_8 = {}^0V_8 \\ ^3V_{11} = {}^4V_{11}\end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$	...	...	...	...	...	...	...	0	...	...	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	−	$^2V_6 - {}^1V_1$	$^3V_6$	$\left\{\begin{matrix}^2V_6 = {}^3V_6 \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n - 2$	1	...	...	...	...	$2n-2$											
18	+	$^1V_1 + {}^2V_7$	$^3V_7$	$\left\{\begin{matrix}^2V_7 = {}^3V_7 \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 3 + 1 = 4$	1	...	...	...	...	...	4										
19	÷	$^3V_6 \div {}^3V_7$	$^1V_9$	$\left\{\begin{matrix}^3V_6 = {}^3V_6 \\ ^3V_7 = {}^3V_7\end{matrix}\right\}$	$= \frac{2n-2}{4}$	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...	$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = A_3\right\}$						
20	×	$^1V_9 \times {}^4V_{11}$	$^5V_{11}$	$\left\{\begin{matrix}^1V_9 = {}^0V_9 \\ ^4V_{11} = {}^5V_{11}\end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$	...	...	...	...	...	...	...	...	0								
21	×	$^1V_{22} \times {}^5V_{11}$	$^0V_{12}$	$\left\{\begin{matrix}^1V_{22} = {}^1V_{22} \\ ^0V_{12} = {}^2V_{12}\end{matrix}\right\}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = B_3 A_3$	...	...	...	...	...	...	...	...	...	...	0	$B_3 A_3$	....	......	B_3		
22	+	$^2V_{12} + {}^2V_{13}$	$^3V_{13}$	$\left\{\begin{matrix}^2V_{12} = {}^0V_{12} \\ ^2V_{13} = {}^3V_{13}\end{matrix}\right\}$	$= A_0 + B_1 A_1 + B_3 A_3$	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{A_3 + B_1 A_1 + B_3 A_3\right\}$				
23	−	$^2V_{10} - {}^1V_1$	$^3V_{10}$	$\left\{\begin{matrix}^2V_{10} = {}^3V_{10} \\ ^1V_1 = {}^1V_1\end{matrix}\right\}$	$= n - 3 (= 1)$	1	...	...	...	...	...	...	...	...	$n-3$							
					Here follows a repetition of Operations thirteen to twenty-three.																	
24	+	$^4V_{13} + {}^0V_{24}$	$^1V_{24}$	$\left\{\begin{matrix}^4V_{13} = {}^0V_{13} \\ ^0V_{24} = {}^1V_{24}\end{matrix}\right\}$	$= B_7$	...	...	...	...	...	...	...	...	...	...	....	....	....	......	......	......	B_7
25	+	$^1V_1 + {}^1V_3$	$^1V_3$	$\left\{\begin{matrix}^1V_1 = {}^1V_1 \\ ^1V_3 = {}^1V_3 \\ ^5V_6 = {}^0V_6 \\ ^5V_7 = {}^0V_7\end{matrix}\right\}$	$= n + 1 = 4 + 1 = 5$ .... by a Variable-card. by a Variable card.	1	...	$n+1$	...	...	0	0										

Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

Number of Operation.	Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data.			Working Variables.										Result Variables.			
						$^1V_1$ 0 0 1 [1]	$^1V_2$ 0 0 2 [2]	$^1V_3$ 0 0 4 [n]	$^0V_4$ 0 0 0	$^0V_5$ 0 0 0	$^0V_6$ 0 0 0	$^0V_7$ 0 0 0	$^0V_8$ 0 0 0	$^0V_9$ 0 0 0	$^0V_{10}$ 0 0 0	$^0V_{11}$ 0 0 0	$^0V_{12}$ 0 0 0	$^0V_{13}$ 0 0 0	$^1V_{21}$ B_1 in a decimal fraction. [B_1]	$^1V_{22}$ B_3 in a decimal fraction. [B_3]	$^1V_{23}$ B_5 in a decimal fraction. [B_5]	$^0V_{24}$... 0 0 0 [B_7]
1	×	$^1V_2 \times {}^1V_3$	$^1V_4, {}^1V_5, {}^1V_6$	$\{^1V_2 = {}^1V_2;\ ^1V_3 = {}^1V_3\}$	$= 2n$	...	2	n	$2n$	$2n$	$2n$											
2	−	$^1V_4 - {}^1V_1$	$^2V_4$	$\{^1V_4 = {}^2V_4;\ ^1V_1 = {}^1V_1\}$	$= 2n - 1$	1	...	...	$2n-1$													
3	+	$^1V_5 + {}^1V_1$	$^2V_5$	$\{^1V_5 = {}^2V_5;\ ^1V_1 = {}^1V_1\}$	$= 2n + 1$	1	...	...	...	$2n+1$												
4	÷	$^2V_5 \div {}^2V_4$	$^1V_{11}$	$\{^2V_5 = {}^0V_5;\ ^2V_4 = {}^0V_4\}$	$= \frac{2n-1}{2n+1}$	...	...	...	0	0	...	...	...	...	...	$\frac{2n-1}{2n+1}$						
5	÷	$^1V_{11} \div {}^1V_2$	$^2V_{11}$	$\{^1V_{11} = {}^2V_{11};\ ^1V_2 = {}^1V_2\}$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$	...	2	...	...	...	...	...	...	...	...	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	−	$^0V_{13} - {}^2V_{11}$	$^1V_{13}$	$\{^2V_{11} = {}^0V_{11};\ ^0V_{13} = {}^1V_{13}\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$	...	...	...	...	...	...	...	...	...	...	0	....	$-\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	−	$^1V_3 - {}^1V_1$	$^1V_{10}$	$\{^1V_3 = {}^1V_3;\ ^1V_1 = {}^1V_1\}$	$= n - 1\ (= 3)$	1	...	n	...	...	...	...	...	...	$n - 1$							
8	+	$^1V_2 + {}^0V_7$	$^1V_7$	$\{^1V_2 = {}^1V_2;\ ^0V_7 = {}^1V_7\}$	$= 2 + 0 = 2$	...	2	...	...	...	...	2										
9	÷	$^1V_6 \div {}^1V_7$	$^3V_{11}$	$\{^1V_6 = {}^1V_6;\ ^0V_{11} = {}^3V_{11}\}$	$= \frac{2n}{2} = A_1$	...	...	...	...	...	$2n$	2	...	...	...	$\frac{2n}{2} = A_1$						
10	×	$^1V_{21} \times {}^3V_{11}$	$^1V_{12}$	$\{^1V_{21} = {}^1V_{21};\ ^3V_{11} = {}^3V_{11}\}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$	...	...	...	...	...	...	...	...	...	...	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	....	B_1			
11	+	$^1V_{12} + {}^1V_{13}$	$^2V_{13}$	$\{^1V_{12} = {}^0V_{12};\ ^1V_{13} = {}^2V_{13}\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$ ...	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	−	$^1V_{10} - {}^1V_1$	$^2V_{10}$	$\{^1V_{10} = {}^2V_{10};\ ^1V_1 = {}^1V_1\}$	$= n - 2\ (= 2)$	1	...	...	...	...	...	...	...	...	$n - 2$							
13	−	$^1V_6 - {}^1V_1$	$^2V_6$	$\{^1V_6 = {}^2V_6;\ ^1V_1 = {}^1V_1\}$	$= 2n - 1$	1	...	...	...	...	$2n-1$											
14	+	$^1V_1 + {}^1V_7$	$^2V_7$	$\{^1V_1 = {}^1V_1;\ ^1V_7 = {}^2V_7\}$	$= 2 + 1 = 3$	1	...	...	...	...	...	3										
15	÷	$^2V_6 \div {}^2V_7$	$^1V_8$	$\{^2V_6 = {}^2V_6;\ ^2V_7 = {}^2V_7\}$	$= \frac{2n-1}{3}$	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$									
16	×	$^1V_8 \times {}^3V_{11}$	$^4V_{11}$	$\{^1V_8 = {}^0V_8;\ ^3V_{11} = {}^4V_{11}\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$	...	...	...	...	...	...	...	0	...	...	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	−	$^2V_6 - {}^1V_1$	$^3V_6$	$\{^2V_6 = {}^3V_6;\ ^1V_1 = {}^1V_1\}$	$= 2n - 2$	1	...	...	...	...	$2n-2$											
18	+	$^1V_1 + {}^2V_7$	$^3V_7$	$\{^2V_7 = {}^3V_7;\ ^1V_1 = {}^1V_1\}$	$= 3 + 1 = 4$	1	...	...	...	...	...	4										
19	÷	$^3V_6 \div {}^3V_7$	$^1V_9$	$\{^3V_6 = {}^3V_6;\ ^3V_7 = {}^3V_7\}$	$= \frac{2n-2}{4}$	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...	$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = A_3\right\}$						
20	×	$^1V_9 \times {}^4V_{11}$	$^5V_{11}$	$\{^1V_9 = {}^0V_9;\ ^4V_{11} = {}^5V_{11}\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$	...	...	...	...	...	...	...	...	0								
21	×	$^1V_{22} \times {}^5V_{11}$	$^0V_{12}$	$\{^1V_{22} = {}^1V_{22};\ ^0V_{12} = {}^2V_{12}\}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = B_3 A_3$	...	...	...	...	...	...	...	...	...	...	0	$B_3 A_3$	....	......	B_3		
22	+	$^2V_{12} + {}^2V_{13}$	$^3V_{13}$	$\{^2V_{12} = {}^0V_{12};\ ^2V_{13} = {}^3V_{13}\}$	$= A_0 + B_1 A_1 + B_3 A_3$	...	...	...	...	...	...	...	...	...	...	....	0	$\{A_3 + B_1 A_1 + B_3 A_3\}$				
23	−	$^2V_{10} - {}^1V_1$	$^3V_{10}$	$\{^2V_{10} = {}^3V_{10};\ ^1V_1 = {}^1V_1\}$	$= n - 3\ (= 1)$	1	...	...	...	...	...	...	...	...	$n - 3$							
Here follows a repetition of Operations thirteen to twenty-three.																						
24	+	$^4V_{13} + {}^0V_{24}$	$^1V_{24}$	$\{^4V_{13} = {}^0V_{13};\ ^0V_{24} = {}^1V_{24}\}$	$= B_7$	...	...	...	...	...	...	...	...	...	...	....	....	....	......	......	......	B_7
25	+	$^1V_1 + {}^1V_3$	$^1V_3$	$\{^1V_1 = {}^1V_1;\ ^1V_3 = {}^1V_3;\ ^5V_6 = {}^0V_6;\ ^5V_7 = {}^0V_7\}$	$= n + 1 = 4 + 1 = 5$ .... by a Variable-card. by a Variable card.	1	...	$n+1$	...	...	0	0										

Program Snippet (GitHub Gist)

```
// ------- A0 -------
/* 01 */ v4 = v5 = v6 = v2 * v3;       // 2n
/* 02 */ v4 = v4 - v1;                 // 2n - 1
/* 03 */ v5 = v5 + v1;                 // 2n + 1

// In Lovelace's diagram, the below appears as v5 / v4, which is incorrect.
/* 04 */ v11 = v4 / v5;                // (2n - 1) / (2n + 1)

/* 05 */ v11 = v11 / v2;               // (1 / 2) * ((2n - 1) / (2n + 1))
/* 06 */ v13 = v13 - v11;              // -(1 / 2) * ((2n - 1) / (2n + 1))
/* 07 */ v10 = v3 - v1;                // (n - 1), set counter?

// On the first loop this calculates B3A3 and adds it on to v13.
// On the second loop this calculates B5A5 and adds it on.
while (v10 > 0)
{
    // ------- B3A3, B5A5 -------
    while (v6 > 2 * v3 - (2 * (v3 - v10) - 2))
    {                                  // First Loop:
        /* 13 */ v6 = v6 - v1;         // 2n - 1
        /* 14 */ v7 = v1 + v7;         // 2 + 1
        /* 15 */ v8 = v6 / v7;         // (2n - 1) / 3
        /* 16 */ v11 = v8 * v11;       // (2n / 2) * ((2n - 1) / 3)
    }

    if (v10 == 2) {
    /* 21 */ v12 = v22 * v11;          // B3 * A3
    } else {
    /* 21 */ v12 = v23 * v11;          // B5 * A5
    }

    // B3A3 = B3 * (2n / 2) * ((2n - 1) / 3) * ((2n - 2) / 4)
```

Resources

- *What Did Ada Lovelace's Program Actually Do?* TwoBitHistory.org
- Sketch of the Analytical Engine
- Translation of Note D to C. (gist)
- Wikipedia

Breakout Discussions

- Introduce yourself to your group; what are you working on this summer?
- What is the most difficult bug you've encountered?
- What is the best thing you've attended so far this summer? And/or what are you most looking forward to?

Prizes!
A prize will be awarded to anyone who shares their bug story at the end of the hour