Ada Lovelace
First Computer Programmer

Learning Leaflet: Women in Science
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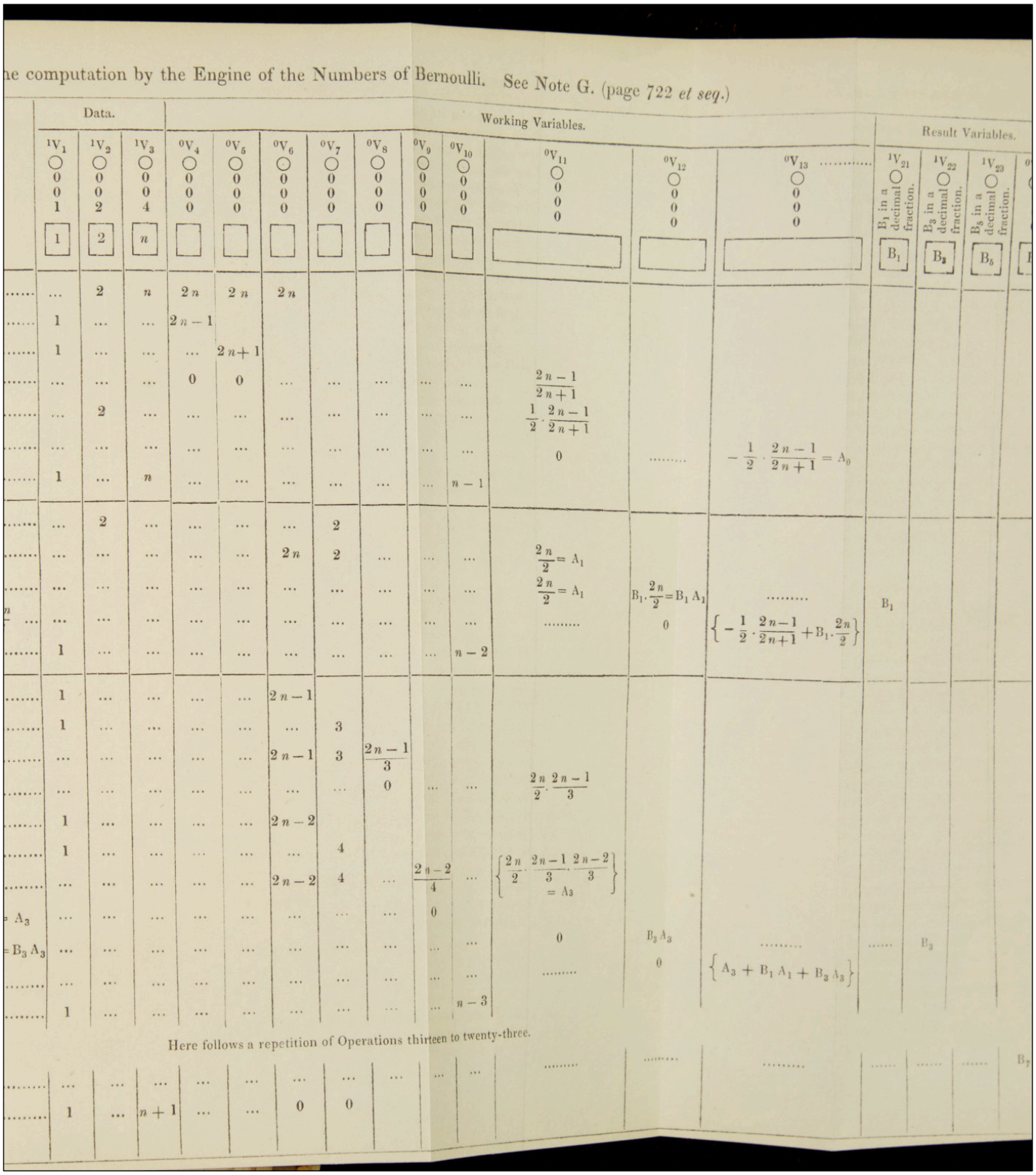


he computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

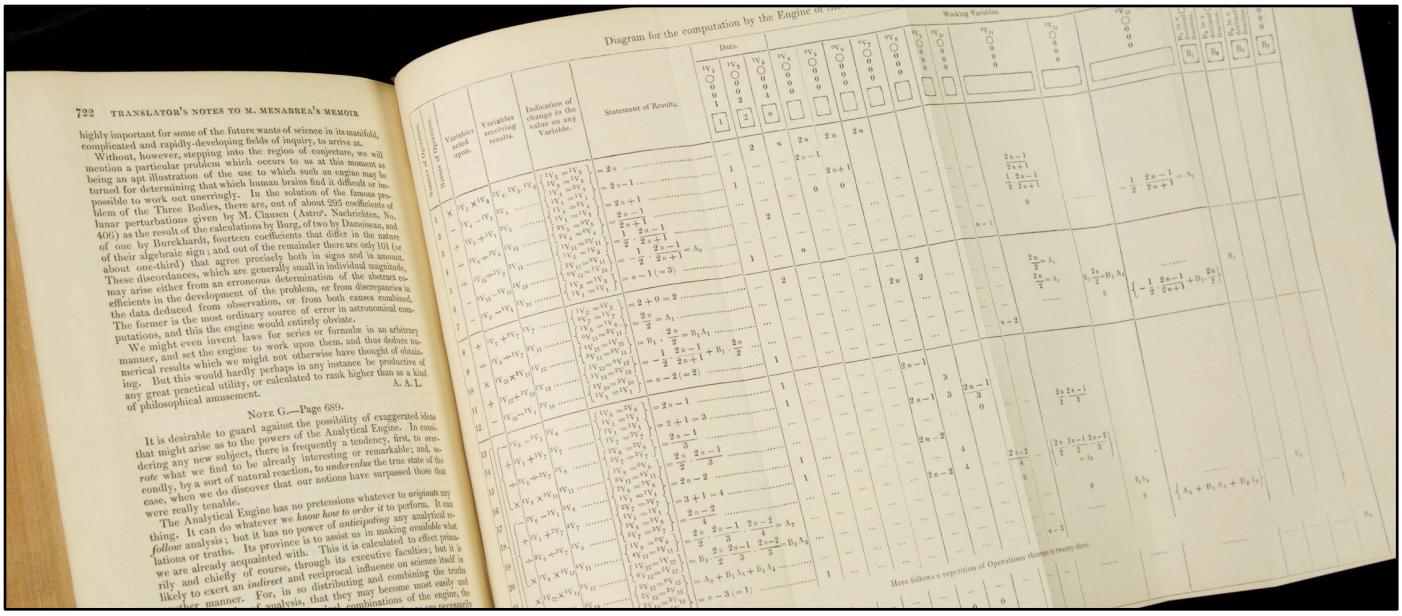
Data.			Working Variables.									Result Variables.			
$^1V_1$ 0 0 0 1 [1]	$^1V_2$ 0 0 0 2 [2]	$^1V_3$ 0 0 0 4 [n]	$^0V_4$ 0 0 0 [ ]	$^0V_5$ 0 0 0 [ ]	$^0V_6$ 0 0 0 [ ]	$^0V_7$ 0 0 0 [ ]	$^0V_8$ 0 0 0 [ ]	$^0V_9$ 0 0 0 [ ]	$^0V_{10}$ 0 0 0 [ ]	$^0V_{11}$ 0 0 0 [ ]	$^0V_{12}$ 0 0 0 [ ]	$^0V_{13}$ 0 0 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]
.....	...	2	n	$2n$	$2n$	$2n$									
.....	1	...	...	$2n-1$											
.....	1	...	...	...	$2n+1$										
.....	...	...	...	0	0	...	...	...	...	...					
.....	...	2	...	...	...	...	...	...	...	...					
.....	...	...	...	...	...	...	...	...	...	...					
.....	1	...	n	...	...	...	...	...	$n-1$	...					
.....	...	2	...	...	...	...	2								
.....	...	...	...	...	...	$2n$	2	...	...	...					
.....	...	...	...	...	...	...	...	...	...	...					
n ...	...	...	...	...	...	...	...	...	...	...					
.....	1	...	...	...	...	...	...	...	$n-2$	...					
.....	1	...	...	...	...	$2n-1$									
.....	1	...	...	...	...	...	3								
.....	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$							
.....	...	...	...	...	...	...	...	0	...	...					
.....	1	...	...	...	...	$2n-2$									
.....	1	...	...	...	...	...	4								
.....	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...					
$= A_3$	...	...	...	...	...	...	...	...	0						
$= B_3 A_3$	...	...	...	...	...	...	...	...	...	...					
.....	...	...	...	...	...	...	...	...	...	...					
.....	1	...	...	...	...	...	...	...	$n-3$	...					

Here follows a repetition of Operations thirteen to twenty-three.

.....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
.....	1	...	$n+1$	...	...	0	0								

Ada Lovelace, "Notes" to a "Sketch of the Analytical Engine Invented by Charles Babbage, by L.F. Menabrea," in *Scientific Memoirs* (London, 1843), vol. 3.

What is the difference between a calculating machine and a computer?



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highly important for some of the future wants of science in its manifold, complicated and rapidly-developing fields of inquiry, to arrive at.

Without, however, stepping into the region of conjecture, we will mention a particular problem which occurs to us at this moment as being an apt illustration of the use to which such an engine may be turned for determining that which human brains find it difficult or impossible to work out unerringly. In the solution of the famous problem of the Three Bodies, there are, out of about 295 coefficients of lunar perturbations given by M. Clausen (Astron. Nachrichten, No. 406) as the result of the calculations by Burg, of two by Damoiseau, and of one by Burckhardt, fourteen coefficients that differ in the nature of their algebraic sign; and out of the remainder there are only 101 (or about one-third) that agree precisely both in signs and in amount. These discordances, which are generally small in individual magnitude, may arise either from an erroneous determination of the abstract efficients in the development of the problem, or from discrepancies in the data deduced from observation, or from both causes combined. The former is the most ordinary source of error in astronomical computations, and this the engine would entirely obviate.

We might even invent laws for series or formulæ in an arbitrary manner, and set the engine to work upon them, and thus deduce numerical results which we might not otherwise have thought of obtaining. But this would hardly perhaps in any instance be productive of any great practical utility, or calculated to rank higher than as a kind of philosophical amusement.

A. A. L.

NOTE G.—Page 689.

It is desirable to guard against the possibility of exaggerated ideas that might arise as to the powers of the Analytical Engine. In considering any new subject, there is frequently a tendency, first, to overrate what we find to be already interesting or remarkable; and, secondly, by a sort of natural reaction, to *underrate* the true state of the case, when we do discover that our notions have surpassed those that were really tenable.

The Analytical Engine has no pretensions whatever to *originate* anything. It can do whatever we *know how to order* it to perform. It can *follow* analysis; but it has no power of *anticipating* any analytical revelations or truths. Its province is to assist us in making available what we are already acquainted with. This it is calculated to effect primarily and chiefly of course, through its executive faculties; but it is likely to exert an *indirect* and reciprocal influence on science itself in another manner. For, in so distributing and combining the truths and formulæ of analysis, that they may become most easily and

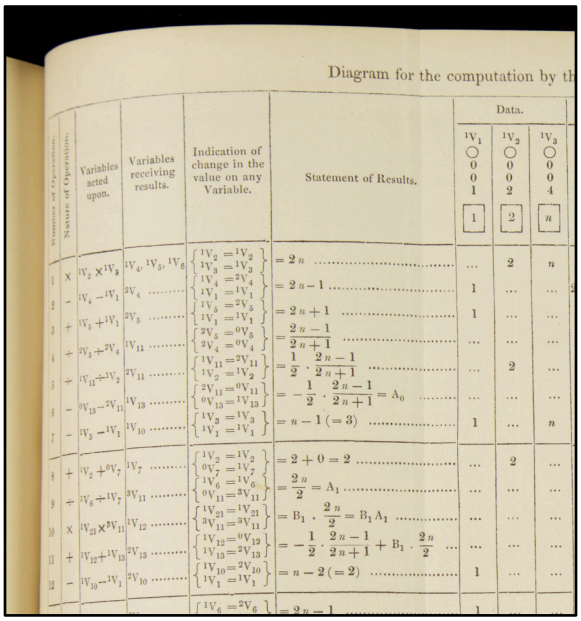
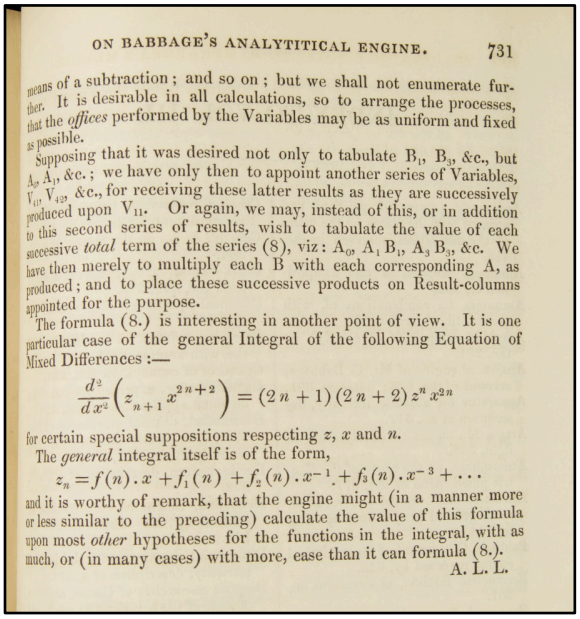


Diagram for the computation by th

Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data. $^1V_1$ 0 0 0 1 [1]	$^1V_2$ 0 0 0 2 [2]	$^1V_3$ 0 0 0 4 [n]
1	× $^1V_2 \times ^1V_3$	$^1V_4, ^1V_5, ^1V_6$	$^1V_2 = ^1V_2$ $^1V_3 = ^1V_3$	$= 2n$	...	2	n
2	− $^1V_4 - ^1V_1$	$^2V_4$	$^1V_4 = ^2V_4$ $^1V_1 = ^1V_1$	$= 2n-1$	1	...	...
3	+ $^1V_5 + ^1V_1$	$^2V_5$	$^1V_5 = ^2V_5$ $^1V_1 = ^1V_1$	$= 2n+1$	1	...	...
4	÷ $^2V_5 \div ^2V_4$	$^1V_{11}$	$^2V_5 = ^0V_5$ $^2V_4 = ^0V_4$	$= \frac{2n-1}{2n+1}$	...	...	...
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	...
6	− $^0V_{13} - ^2V_{11}$	$^1V_{13}$	$^2V_{11} = ^0V_{11}$ $^0V_{13} = ^1V_{13}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$	...	...	...
7	− $^1V_3 - ^1V_1$	$^1V_{10}$	$^1V_3 = ^1V_3$ $^1V_1 = ^1V_1$	$= n-1\ (=3)$	1	...	n
8	+ $^1V_2 + ^0V_7$	$^1V_7$	$^1V_2 = ^1V_2$ $^0V_7 = ^1V_7$	$= 2+0=2$	...	2	...
9	÷ $^1V_6 \div ^1V_7$	$^3V_{11}$	$^1V_6 = ^1V_6$ $^0V_{11} = ^3V_{11}$	$= \frac{2n}{2} = A_1$	...	...	...
10	× $^1V_{21} \times ^3V_{11}$	$^1V_{12}$	$^1V_{21} = ^1V_{21}$ $^3V_{11} = ^3V_{11}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$	...	...	...
11	+ $^1V_{12} + ^1V_{13}$	$^2V_{13}$	$^1V_{12} = ^0V_{12}$ $^1V_{13} = ^2V_{13}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$ ...	...	...	...
12	− $^1V_{10} - ^1V_1$	$^2V_{10}$	$^1V_{10} = ^2V_{10}$ $^1V_1 = ^1V_1$	$= n-2\ (=2)$	1	...	...
			$^1V_6 = ^2V_6$	$= 2n-1$	1		



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means of a subtraction; and so on; but we shall not enumerate further. It is desirable in all calculations, so to arrange the processes, that the *offices* performed by the Variables may be as uniform and fixed as possible.

Supposing that it was desired not only to tabulate B_1, B_3, &c., but A_0, A_1, &c.; we have only then to appoint another series of Variables, V_{41}, V_{43}, &c., for receiving these latter results as they are successively produced upon V_{11}. Or again, we may, instead of this, or in addition to this second series of results, wish to tabulate the value of each successive *total* term of the series (8), viz: A_0, $A_1 B_1$, $A_2 B_2$, &c. We have then merely to multiply each B with each corresponding A, as produced; and to place these successive products on Result-columns appointed for the purpose.

The formula (8.) is interesting in another point of view. It is one particular case of the general Integral of the following Equation of Mixed Differences :—

$$\frac{d^2}{dx^2}\left(z_{n+1}\, x^{2n+2}\right) = (2n+1)(2n+2)\, z^n x^{2n}$$

for certain special suppositions respecting z, x and n.

The *general* integral itself is of the form,

$$z_n = f(n) \cdot x + f_1(n) + f_2(n) \cdot x^{-1} + f_3(n) \cdot x^{-3} + \ldots$$

and it is worthy of remark, that the engine might (in a manner more or less similar to the preceding) calculate the value of this formula upon most *other* hypotheses for the functions in the integral, with as much, or (in many cases) with more, ease than it can formula (8.).

A. L. L.

Ada Lovelace: First Computer Programmer

Charles Babbage designed two kinds of mechanical computational machines: a "difference engine," or calculating machine; and an "analytical engine," which was far more. In 1840, Babbage presented his design for the "analytical engine" to a group of mathematical engineers in Turin, Italy. One of them, Luigi Menabrea, who would later become Prime Minister of Italy, published an account of Babbage's design in Geneva. With Babbage's encouragement, the daughter of Lord Byron, Augusta Ada King, Countess of Lovelace, translated Menabrea's article into English and added her own substantive commentary. Lovelace's notes went considerably beyond what Babbage and Menabrea had written. Her lengthy appended notes amount to 40 pages of very dense text compared with only 24 pages, lightly spaced, for Menabrea's article. Lovelace explained how Babbage's "analytical engine," if constructed, would amount to a programmable computer rather than merely a calculator. It would take input from punch cards, and store variables for use in diverse sequential operations. These 19th century mechanical operations are functionally equivalent to the conditional branching, looping, and parallel processing operations of early electronic computers. Although she specified how Babbage's engine could generate a Bernoulli series of numbers, Lovelace argued for the wider potential of the engine to produce analytical results beyond the realm of mathematics.

Kerry Magruder and Brent Purkaple