MATHEMATICS-MECHANICS

"A Classic of Science"— The Difference Engine

CHARLES BABBAGE, the famous British Mathematician, tells how, when only about 20 years old, he planned the most complicated calculating machine ever designed:

"ONE evening I was sitting in the rooms of the Analytical Society, at Cambridge, my head leaning forward on the table in a kind of dreamy mood, with a table of logarithms lying open before me. Another member, coming into the room, and seeing me half asleep, called out, 'Well, Babbage, what are you dreaming about?' to which I replied, 'I am thinking that all these tables (pointing to the logarithms) might be calculated by machinery'."

The first machine which Babbage invented computed tables of related figures by adding or substracting the differences between the numbers, and was hence called the Difference Engine. An even more complex machine, the Analytical Engine, was projected. It was to solve algebraic problems by amechanism operated by perforated cards, like a jacquard loom or a modern self-playing piano. After spending his life and fortune on the plans and models of his machines, Babbage suffered the usual heartbreak of the inventor who is ahead of his times.

The Classic here reprinted gives Babbage's idea of what should be expected of a calculating machine.

THE EXPOSITION OF 1851; or, Views of the Industry, the Science, and the Government, of England. By Charles Babbage, Esq., London.

I HAVE met in the course of my inquiries with four cases of obstacles presenting the appearance of impossibilities. As these form a very interesting chapter in the history of the human mind, and are on the one hand connected with some of the simplest elements of mechanism, and on the other with some of the highest principles of philosophy, I shall endeavour to explain them in a short, and, I hope, somewhat popular manner, to those who have a very moderate share of mathematical knowledge. Those of my readers to whom they may not be sufficiently interesting, will, I hope, excuse the interruption, and pass on to the succeeding chapters.

The first difficulty arose at an early stage of the Analytical Engine. The mechanism necessary to add one number to another, if the carriage of the tens be neglected, is very simple. Various modes had been devised and drawings of about a dozen contrivances for carrying the tens had been made. The same general principle pervaded all of them. Each figure wheel when receiving addition, in the act of passing from nine to ten caused a lever to be put aside. An axis with arms arranged spirally upon it then revolved, and commencing with the lowest figure replaced successively those levers which might have been put aside during the addition. This replacing action upon the levers caused unity to be added to the figure wheel next above. The numerical example below will illustrate the process.

597,999 201,001	Numbers to be added
798,990	Sum without any carriage.
1	Puts aside lever acting on tens.
798,900	First spiral arms adds tens and
1	puts aside the next lever.
798,000	Second spiral arm adds hundreds, and puts aside the
1	next lever.
799,000	Third spiral arm adds thousands.

Now there is in this mechanism a certain analogy with the act of memory. The lever thrust aside by the passage of the tens, is the equivalent of the note of an event made in the memory, whilst the spiral arm, acting at an after time upon the lever put aside, in some measure resembles the endeavours made to recollect a fact.

It will be observed that in these modes of *carrying*, the action must be *successive*. Supposing a number to consist of thirty places of figures, each of which is a nine, then if any other number of thirty figures be added to it, since the addition of each figure to the corresponding one takes place at the same time, the whole addition will only occupy nine units of time. But since the number added may be unity, the carriages may possibly amount to twenty-nine. Consequently the time of making the carriages may be more than three times as long as that required for addition.

The time thus occupied was, it is true, very considerably shortened in the Difference Engine: but when the Analytical Engine was to be contrived, it became essentially necessary to diminish it still further. After much time fruitlessly expended in many contrivances and drawings, a very different principle, which seemed indeed at first to be impossible, suggested itself.

Carrying Tens

It is evident that whenever a carriage is conveyed to the figure above, if that figure happen to be a nine, a new carriage must then take place, and so on as far as the nines extend. Now the principle sought to be expressed in mechanism amounted to this.

1st. That a lever should be put aside, as before, on the passage of a figure-wheel from nine to ten.

2d. That the engine should then ascertain the position of all those nines which by carriage would ultimately become zero, and give notice of new carriages; that, foreseeing those events, it should anticipate the result by making all the carriages simultaneously.

This was ultimately accomplished,

Next Week's

CLASSIC OF SCIENCE

JEAN BAPTISTE JOSEPH FOURIER

Famous French mathematician and scientist and able engineer to Napoleon in Egypt on

THE THEORY OF HEAT

and many different mechanical contrivances fulfilling these conditions were drawn. The former part of this mechanism bears an analogy to memory, the latter to foresight. The apparatus remembers as it were one set of events, the transits from nine to ten: examines what nines are found in certain critical places: then, in consequence of the concurrence of these events, acts at once so as to anticipate other actions that would have happened at a more distant period, had less artificial means been used.

The second apparent impossibility seemed to present far greater difficulty. Fortunately it was not one of immediate *practical* importance, although as a question of philosophical inquiry it possessed the highest interest. I had frequently discussed with Mrs. Somerville and my highly gifted friend the late Professor M'Cullagh, of Dublin, the question whether it was possible that we should be able to treat algebraic formulæ by means of machinery. The result of many inquiries led to the conclusion, that if not really impossible, it was almost hopeless. . . .

This is not a fit place to enter into the detail of the means employed, further than to observe, that it was found possible to evade the difficulty, by connecting *indefinite* number with the *infinite in time* instead of with the *infinite in space.*

The solution of this difficulty being found, and the discovery of another principle having been made, namely—that *the nature of a function might be indicated by its position*—algebra, in all its most abstract forms, was placed completely within the reach of mechanism.

Uses Logarithms

The third difficulty that presented itself was one which I had long before anticipated. It was proposed to me nearly at the same time by three of the most eminent cultivators of analysis then existing, M. Jacobi, M. Bessel, and Professor M'Cullagh, who were examining the drawings of the Analytical Engine. The question they proposed was this:—How would the Analytical Engine be able to treat calculations in which the use of tables of logarithms, sines, &c. or any other tabular numbers would be required?

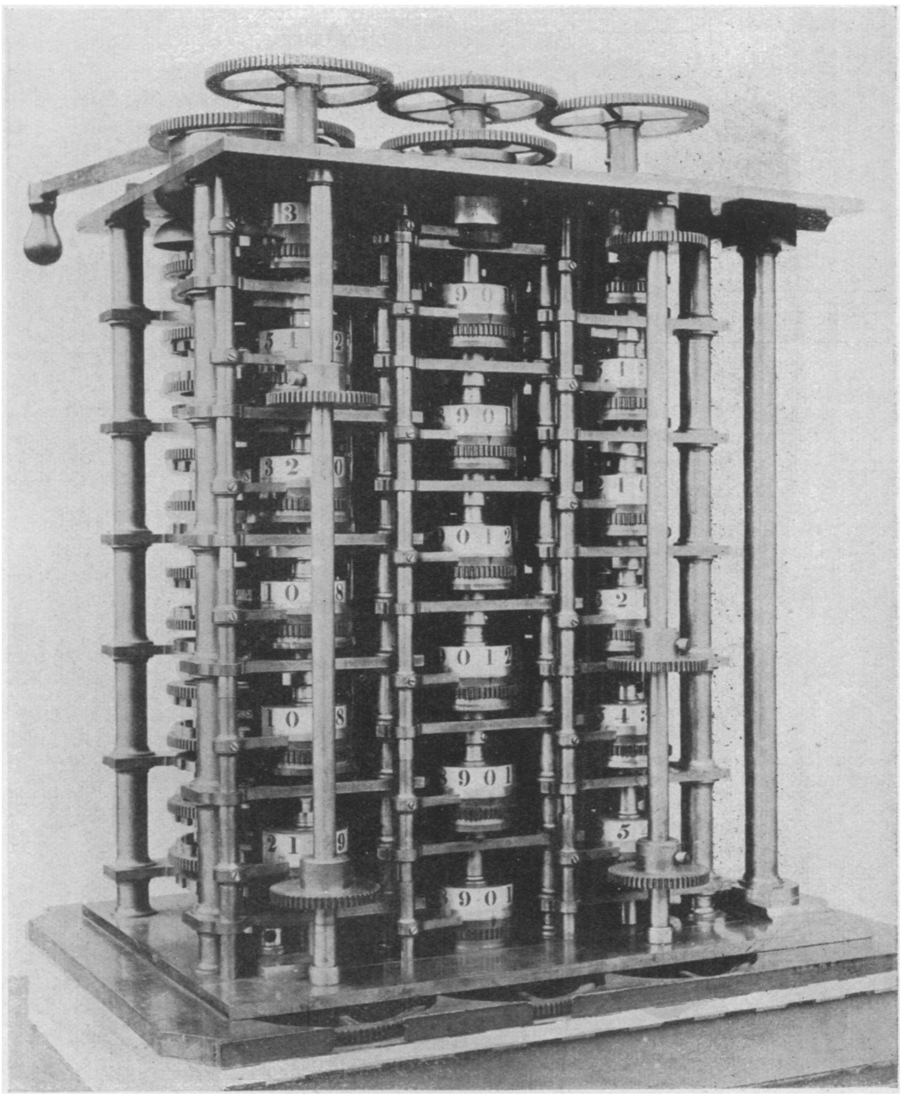
My reply was, that as at the time logarithms were invented, it became necessary to remodel the whole of the formulæ of Trigonometry, in order to adapt it to the new instrument of calculation: so when the Analytical Engine is made, it will be desirable to transform all formulæ containing tabular numbers into others better adapted to the use of such a machine. This, I replied, is the answer I give to you as mathematicians; but I added, that for others less skilled in our science, I had another answer: namely—

Asks for What It Wants

That the engine might be so arranged that wherever tabular numbers of any kind, occurred in a formula given it to compute, it would on arriving at any required tabular number, as for instance, if it required the logarithm of 1207 stop itself, and ring a bell to call the attendant, who would find written at a certain part of the machine, "Wanted log. of 1207." The attendant would then fetch from tables previously computed by the engine, the logarithm it required, and placing it in the proper place, would lift a detent, permitting the engine to continue its work.

The next step of the machine, on receiving the tabular number (in this case the logarithm of 1207) would be to *verify* the fact of its being really that logarithm. In case no mistake had been made by the attendant, the engine would use the given tabular number, and go on with its work until some other tabular number were required, when the same process would be repeated. If, however, any mistake had been made by the attendant, and a wrong logarithm had been accidentally given to the engine, it would have discovered the mistake, and have rung a louder bell to call the attention of its guide, who on looking at the proper place, would see a plate above the logarithm he had just put in with the word *"wrong"* engraved upon it.

By such means it would be perfectly



A FRAGMENT OF THE DIFFERENCE ENGINE
The Only Part Actually Built. It is in the South Kensington Museum, London

possible to make all calculations requiring tabular numbers, without the chance of error.

Although such a plan does not seem absolutely impossible, it has always excited, in those informed of it for the first time, the greatest surprise. How, it has been often asked, does it happen if the engine knows when the *wrong* logarithm is offered to it, that it does not also know the right one; and if so, what is the necessity of having recourse to the attendant to supply it? The solution of this difficulty is accomplished by the very simplest means.

Science News Letter, October 4, 1930

PHYSICS-METEOROLOGY

Cosmic Rays Excel Barometer As Indicator of Overhead Air

Dr. Millikan Made a Thorough Check of New Findings Before Presenting Them to National Academy of Sciences

A PRACTICAL use for the cosmic rays that bombard the earth from outer space with amazing penetration and shortness of wave length has been discovered by Dr. Robert A. Millikan, Nobel prize physicist and president of the California Institute of Technology and who, only a few years ago, began to study these rays intensively.

He has discovered within the last few weeks that the instrument used for measuring the cosmic radiation, called an electroscope, as perfected for his present researches, will measure the depth of air overhead at any part of the earth with an accuracy far surpassing that given by the familiar meteorological instrument known as the barometer.

Uses Cosmic Ray Electroscope

The cosmic ray electroscope he has reported to the National Academy of Sciences, "can furnish us with new data about what is happening in the upper air and must assist in the important problem of predicting, if not controlling, meteorological and geophysical events."

Dr. Millikan made his discovery of everyday utilization of this hitherto research instrument during the course of an expedition to within seven hundred miles of the North Pole and two hundred miles of the north magetic pole.

Carrying five hundred pounds of scientific instruments and slabs of lead with which to shield them from earthly radiations, Dr. Millikan traveled over the new train-a-week railroad to Fort Churchill in Canada on the west side of Hudson Bay. There he set up his electroscope and made observations night and day for a week. He returned from this trip two weeks ago.

He desired observations close to the magnetic pole in order to test the theories of physicists, with whom he disagreed, who held that the cosmic rays were not waves in the ether like light, heat and X-rays, but high-speed electrons. Professor P. S. Epstein, one of Dr. Millikan's colleagues, explained that mathematical theory shows that if the penetrating cosmic radiations were high-speed electrons they should be deflected in the magnetic field of the earth and therefore be much more plentiful near the magnetic poles.

The observations show that the cosmic radiation is an ether wave radiation that comes to the earth with constant and uniform intensity at all latitudes. Observed variations in it are due to changes in the thickness of the shielding air through which they must pass to reach the surface. This fact allows Dr. Millikan to propose that the electrometer be used as an instrumental mate to the barometer in every weather bureau station.

Dr. Millikan reaffirmed his belief that cosmic rays are signals from the depths of space of the continuous formation there of the common abundant elements helium, oxygen, silicon and iron out of hydrogen.

This is hopeful reassurance to those who have felt that the whole universe is like a great watch running down. There is evidence in the stars and nebulæ that matter is being changed into light and therefore dissipated to the ends of the universe. Dr. Millikan's view indicates that somewhere there may be a rebuilding of matter in progress.

Science News Letter, October 4, 1930

ZOOLOGY

Borneo Monkeys Imitate Men With Both Nose and Voice

ONE of Nature's most striking living caricatures is the proboscis monkey which lives in the deep forests of Borneo. A group of these creatures shown as they appear in their home among the branches of a pongyet tree is on exhibition in Carl E. Akeley Memorial Hall at Field Museum of Natural History.

The proboscis monkey gets its name from its very prominent and peculiarly shaped long nose, which gives its face almost the exact appearance of certain types of low comedians who appear on the stage with false noses. Its other