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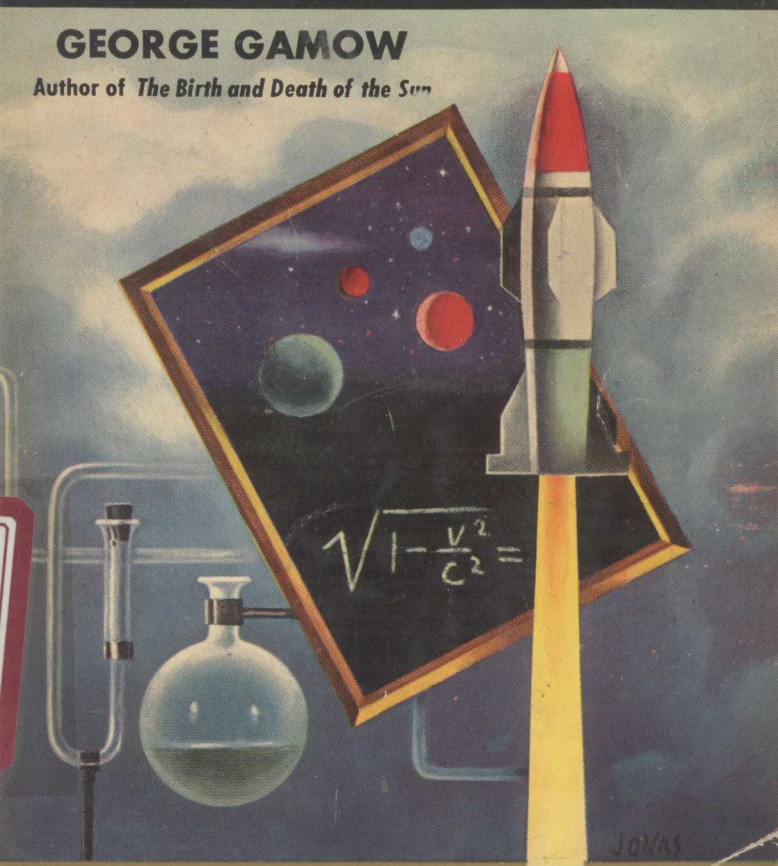
The Most Interesting Facts and Theories of Modern Science Explained for the Layman

ONE TWO THREE···INFINITY

Facts and Speculations of Science

GEORGE GAMOW

Author of *The Birth and Death of the Sun*



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One Two Three . . . INFINITY

FACTS & SPECULATIONS of SCIENCE

by GEORGE GAMOW
PROFESSOR OF THEORETICAL PHYSICS
GEORGE WASHINGTON UNIVERSITY

ILLUSTRATED by the AUTHOR

NAL MENTOR BOOKS A MENTOR BOOK
Published by THE NEW AMERICAN LIBRARY

Published as a MENTOR BOOK
By Arrangement with The Viking Press

FIRST PRINTING, NOVEMBER, 1953

To My Son IGOR
Who Would Rather Be A Cowboy

MENTOR BOOKS are published by
The New American Library of World Literature, Inc.
501 Madison Avenue, New York 22, New York

PRINTED IN THE UNITED STATES OF AMERICA

"The time has come," the Walrus said,
"To talk of many things" . . .
LEWIS CARROLL, *Through the Looking-Glass*

Preface

. . . of atoms, stars, and nebulae, of entropy and genes; and whether one can bend space, and why the rocket shrinks. And indeed, in the course of this book we are going to discuss all these topics, and also many others of equal interest.

The book originated as an attempt to collect the most interesting facts and theories of modern science in such a way as to give the reader a general picture of the universe in its microscopic and macroscopic manifestations, as it presents itself to the eye of the scientist of today. In carrying out this broad plan, I have made no attempt to tell the whole story, knowing that any such attempt would inevitably result in an encyclopedia of many volumes. At the same time the subjects to be discussed have been selected so as to survey briefly the entire field of basic scientific knowledge, leaving no corner untouched.

Selection of subjects according to their importance and degree of interest, rather than according to their simplicity, necessarily has resulted in a certain unevenness of presentation. Some chapters of the book are simple enough to be understood by a child, whereas others will require some little concentration and study to be completely understood. It is hoped, however, that the layman reader will not encounter too serious difficulties in reading the book.

It will be noticed that the last part of the book, which discusses the "Macrocosmos," is considerably shorter than the part on "Microcosmos." This is primarily because I have already discussed in detail so many problems pertaining to the macrocosmos in *The Birth and Death of the Sun*, and *Biography of the Earth*,[1] and further detailed discussion here would be a tedious repetition. Therefore in this part I have

[1] The Viking Press, New York, 1940 and 1941, respectively; New American Library Mentor editions, 1945 and 1948, respectively.

restricted myself to a general account of physical facts and events in the world of planets, stars, and nebulae and the laws that govern them, going into greater detail only in discussing problems upon which new light has been shed by the advance of scientific knowledge during the last few years. Following this principle I have given especial attention to the recent views according to which vast stellar explosions, known as "supernovae," are caused by the so-called "neutrinos," the smallest particles known in physics, and the new planetary theory, which abolishes the currently accepted views that planets originated as the result of collisions between the sun and some other stars, and re-establishes the old half-forgotten views of Kant and Laplace.

I want to express my thanks to numerous artists and illustrators whose work, topologically transformed (see Section II, Ch. III), has served as the basis for many illustrations adorning the book. Above all my thanks are due to my young friend Marina von Neumann, who claims that she knows everything better than her famous father does, except, of course, mathematics, which she says she knows only equally well. After she had read in manuscript some of the chapters of the book, and told me about numerous things in it which she could not understand, I finally decided that this book is not for children as I had originally intended it to be.

G. GAMOW

George Washington University
Washington, D. C.
December 1, 1946

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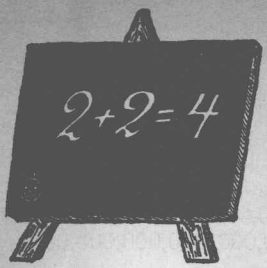
PLATES *(between pages 160 and 161)*

ILLUSTRATIONS IN TEXT



PART I

Playing with Numbers

CHAPTER I

Big Numbers

1. *HOW HIGH CAN YOU COUNT?*

THERE IS A STORY about two Hungarian aristocrats who decided to play a game in which the one who calls the largest number wins.

"Well," said one of them, "you name your number first."

After a few minutes of hard mental work the second aristocrat finally named the largest number he could think of.

"Three," he said.

Now it was the turn of the first one to do the thinking, but after a quarter of an hour he finally gave up.

"You've won," he agreed.

Of course these two Hungarian aristocrats do not represent a very high degree of intelligence[1] and this story is probably just a malicious slander, but such a conversation might actually have taken place if the two men had been, not Hungarians, but Hottentots. We have it indeed on the authority of African explorers that many Hottentot tribes do not have in their vocabulary the names for numbers larger than three. Ask a native down there how many sons he has or how many enemies he has slain, and if the number is more than three he will answer "many." Thus in the Hottentot country in the art of counting fierce warriors would be beaten by an American child of kindergarten age who could boast the ability to count up to ten!

Nowadays we are quite accustomed to the idea that we

[1] This statement can be supported by another story of the same collection in which a group of Hungarian aristocrats lost their way hiking in the Alps. One of them, it is said, took out a map, and after studying it for a long time, exclaimed: "Now I know where we are!" "Where?" asked the others. "See that big mountain over there? We are right on top of it."

can write as big a number as we please—whether it is to represent war expenditures in cents, or stellar distances in inches—by simply setting down a sufficient number of zeros on the right side of some figure. You can put in zeros until your hand gets tired, and before you know it you will have a number larger than even the total number of atoms in the universe,[2] which, incidentally, is 300,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000.

Or you may write it in this shorter form: $3 \cdot 10^{74}$.

Here the little number ^{74} above and to the right of 10 indicates that there must be that many zeros written out, or, in other words, 3 must be multiplied by 10 seventy-four times.

But this "arithmetic-made-easy" system was not known in ancient times. In fact it was invented less than two thousand years ago by some unknown Indian mathematician. Before his great discovery—and it *was* a great discovery, although we usually do not realize it—numbers were written by using a special symbol for each of what we now call decimal units, and repeating this symbol as many times as there were units. For example the number 8732 was written by ancient Egyptians:

whereas a clerk in Caesar's office would have represented it in this form:

MMMMMMMMDCCXXXII

The latter notations must be familiar to you, since Roman numerals are still used sometimes—to indicate the volumes or chapters of a book, or to give the date of a historical event on a pompous memorial tablet. Since, however, the needs of ancient accounting did not exceed the numbers of a few thousands, the symbols for higher decimal units were nonexistent, and an ancient Roman, no matter how well trained in arithmetic, would have been extremely embarrassed if he had been asked to write "one million." The best he could have done to comply with the request, would have been to write one thousand *M's* in succession, which would have taken many hours of hard work (Figure 1).

[2] Measured as far as the largest telescope can penetrate.