Galaxy SCIENCE FICTION

JULY 1956

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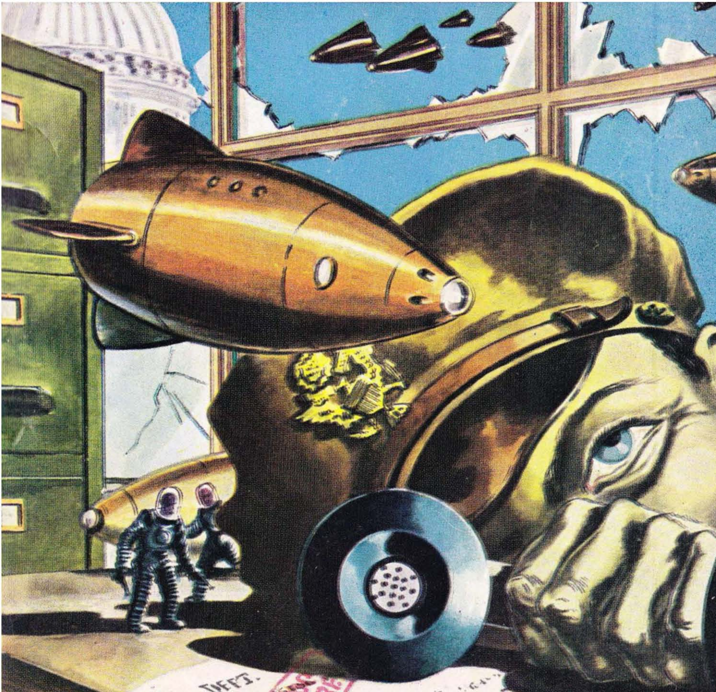

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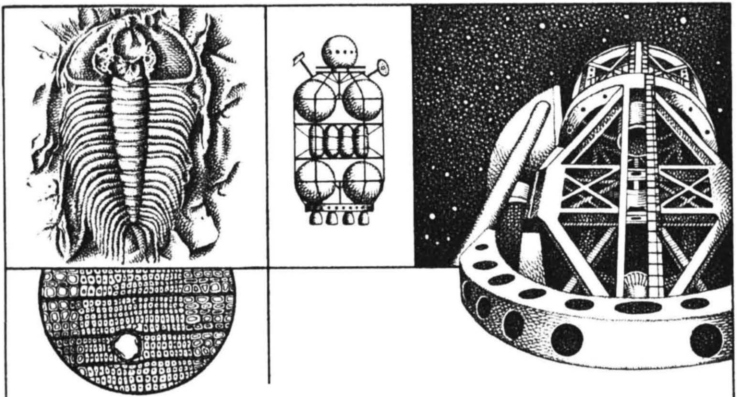
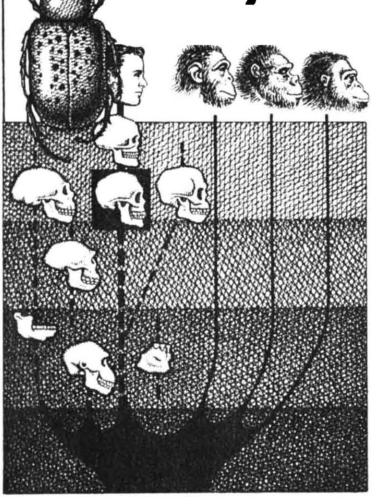


for your information

By WILLY LEY



WELCOME TO REALITY, C-TI

SORTING old correspondence, I just came across a typewritten page which was the beginning of a GALAXY column I had started and did not finish.

I don't recall any more why I changed my mind then, but because of certain clues I know that it was written during the latter part of January, 1955. Here is what I wrote then:

"If contra-terrene matter does not exist, Nature performed an elaborate hoax last year in order to make us believe that it does. Some time during 1954 — date undisclosed — a Skyhook balloon hovered for six hours at a height of a little more than 10,000 feet over Texas. It had been released from Goodfellow Air Force Base in Texas and was part of a joint research project of the Office of Naval Research and the Atomic Energy Commission. The equipment carried in the gondola was of the kind that detects and records cosmic rays.

"When the 'catch' was examined later by Professor Marcel Schein and his colleagues of the Department of Physics of the University of Chicago, they saw that they had indeed caught something unusual. Nothing like it had ever been seen before — it was a 'pure photon shower.' Twenty-one photons were counted in a very small space, with energies from somewhat below 1000 million electron volts to as much as 20,000 million electron volts.

"The total energy release amounted to 10^{16} (or 10,000 million million) electron volts. This in itself would be fantastic and new enough. But when the scientists looked for the heavy charged particles which one would expect as the cause of such a burst, there weren't any."

THIS is as far as I got then. Now, only one year later, the whole thing is outdated.

We no longer have to say that such a photon shower must have been caused by a particle of contra-terrene matter. (Dr. Zwicky had predicted in a letter published in vol. 48, 1935, of the *Physical Review* that such particles could be found only at extreme altitudes.) We no longer have to quote this case as possible evidence for the probable existence of contra-terrene matter.

In fact, it does not matter if this particular case is never explained down to the last photon. For in October, 1955, contra-terrene matter was made at the University of California. This matter being what it is, it is a good thing that they can make it only an atom at a time.

Contra-terrene matter, despite apparent evidence to the contrary, was not thought up by a science fiction writer. It appeared in print for the first time in 1934 in a very technical work with the title *Die moderne Atomtheorie* (Modern Atomic Theory) which was a symposium published by Professor W. Heisenberg, a Nobel Prize winner. The chapter discussing the possibility of "reverse matter" was by another Nobel Prize winner, Dr. P. A. M. Dirac.

Dirac reasoned thus: There

was a small particle carrying a negative charge, the electron. Its opposite number was the proton, carrying a positive charge, but more than 1800 times as massive as the electron. Then there was the neutron, about as massive as the proton, but without any electrical charge.

Dirac concluded that there should be another set of atomic particles, namely the "anti-electron" and the "anti-proton." The anti-electron should have the same mass as an electron, but carrying a positive charge. The anti-proton, of course, would have the mass of the proton, but with a negative charge.

EVERY ordinary atom that we know consists of a nucleus of protons and neutrons, surrounded by a number of electrons arranged in several layers, called shells. If Dirac's two unknown particles existed, there should be a matter of an entirely different type, with negatively charged anti-protons in the nucleus and surrounded by anti-electrons.

Theoretically you could have a counterpart of every element built up in this matter. To the eye, there would be no difference between ordinary (or "terrene") iron and such contra-terrene iron. Most likely it would have the same melting point. The spectroscope could not tell them apart. But if the twain should meet, they would utterly annihilate each other with nothing left but pure energy. Of course iron did not have to meet iron; contra-terrene iron meeting terrene air would produce the same effect.

Dirac's "anti-electron" was actually discovered some time later and became known as a positron.

It remained to find the anti-proton, tentatively called "negatron." But that was not easy. Even if such matter existed elsewhere in space, it could not penetrate the atmosphere. It would make only a very bright flash at very high altitudes and such a bright flash would not be much of a proof.

V. Rojansky calculated in 1940 that a contra-terrene iron meteorite, if it was to reach the surface, would have to be 16 inches in diameter and 60 inches in length. Even then it had to fall without tumbling or else it would be consumed completely while still falling.

There were a few cases on record that looked suspicious in the light of this theory, the best known being the great Siberian meteorite of 1908. But since, by definition, no meteoritic matter could be left, there could never be any palpable evidence. And as the years wore on, several scientists tried to find reasons why the anti-proton was "unnecessary" and "therefore" probably did not exist.

Well, anti-protons have now been produced in the laboratory. Naturally they lasted for only a tiny fraction of a second with all that inimical terrene matter around. But they could be observed. They were there and — surprise! — their so-called cross section turned out to be about double of that of the proton. Maybe the spectroscope will still be useful; nobody can tell at the moment. But knowing now what to go after, we'll know soon.

SQUARE AND CIRCLE

THE year was 1775 A.D. The most important scientific body then in existence — overshadowing even the Royal Society of London to all but Englishmen — namely the Academy of Sciences in Paris, announced a resolution which said that the Academy would no longer investigate or examine alleged solutions of the problem of squaring the circle which might be submitted. The same went for the so-called Delian problem of doubling a cube or for the trisection of angles.

Dissemination of news was not what it is now in 1775. Many people outside of Paris engaged in these three problems apparently did not learn that the Academy had declared them, by implication, to be insoluble. Papers and pamphlets continued to come in. But one has the feeling that, even if the authors of these papers had learned about the Academy's attitude, they would not have been discouraged, for that is something you cannot do to a true circle squarer.

As regards the other two problems, the number of people addicted to them seems to have been smaller at any time in history. Speaking of the present, I can only say that I have never met anybody who spent his evenings trying to double a cube. I did meet three or four tri-sectors, but I have come across at least half a dozen circle squarers. It is this particular problem which seems to have held, and still holds, a fascination that simply cannot be understood by the non-addict.

Interestingly enough, the circle squarers of the more recent past — say the last hundred years — always invented a so-called "good-reason" for their endeavors. They thought and said that the squaring of the circle would also reveal the Secret of the Universe — why and how, in the name of Pythagoras, and which secret did they mean? — or else they were convinced that somebody, somewhere, had substantial sums of money waiting to be awarded as a prize to the successful genius.

While there have been money prizes for various mathematical problems at one time or another, it so happens that there never was one for that particular problem—except in the sense that at least two people offered prizes for finding a mistake in their solutions. One of these two offered a thousand dollars (at a time when four dollars was a good week's pay) and the other offered fifty pieces of gold. Both had to pay within a few years after offering the rewards.

But I once knew a circle squarer who confided to me that the Government had a secret prize in readiness. That a secret prize is a plain absurdity just never occurred to him. Incidentally, he did not claim to have found the solution.

WELL, to go into the story itself, let's look at the problem first. The problem is to construct a square of *precisely the* same area as a given circle. Emphasis is on the word *precisely;* a difference of a mere one-tenth of one per cent or even of a ten-millionth of one per cent is not acceptable. It has to be precise. Along with this demand there goes a condition. The condition of that square has to be accomplished by using only two tools: a pair of compasses and an unmarked straight edge. If that classical condition is neglected, a solution can be found. Leonardo da Vinci is the author of what is probably the earliest one.

To construct a square of the same area as a given circle, da Vinci made a roller of the same diameter as the circle. The thickness of the roller was one-half of the radius of that circle — one-quarter of its diameter. Running the inked roller on a sheet of paper for precisely one revolution resulted in a rather long and narrow rectangle of the same area as the circle. To convert the rectangle into a square by geometrical construction was elementary. With instruments in addition to the pair of compasses and the unmarked ruler, it can be done.

But when you do observe the classical condition, things have a habit of getting tough very fast — and of staying that way. One way tried by many is shown in Fig. 1. There you have the circle. You put one square inside it and another one around it; obviously the inscribed square is smaller in area than the circle, while the circumscribed square is larger. The wanted square is evidently intermediate in size. To construct it, we halve the distance between the two squares and draw a third one (dotted line in Fig. 1). It looks as if it might be of the

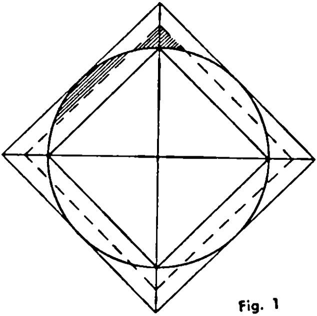


Fig. 1

right size.

To prove that it is, you have to prove that the protruding segment of the circle and the protruding corner of the square are equal in area — to make this more easily visible, one of each has been shaded in the drawing. Well, in this particular case, the two areas are not equal, as one can easily see. But if you had a square of a slightly larger size where the two areas look equal, you could not prove their equality by any means, even if it happens to be the case of sheer accident.

JUMPING somewhat ahead of the actual historical development, one may ask whether there was a reason why so many people through so many centuries believed that it could be done. There was. There was a case where it could be proved that a figure bounded by pieces of circles was precisely equal in area to another figure bounded by straight lines.

This case is known to mathematicians as the menisci or lunulae of Hippocrates of Chios, who lived in Athens during the second half of the fifth century B.C. It may be wrong to say that he caused the waste of more manhours than anybody since his time, but he certainly ranks high among inventors of misleading evidence.

Look at Fig. 2. You have there a triangle in which one angle is a right angle and both cathetes and the hypotenuse are adorned with a half circle each. The half circle A has, of course, the largest area, while the areas of E and D are smaller. None of them has an area which is either equal to or a simple fraction of the area T of the triangle. But $E + D = A$; the two smaller semicircles taken together have the same area as the larger one.

Now we redraw the same thing as shown in Fig. 2B. The largest of the three semicircles then splits each of the smaller ones into two unequal areas. The former area E now consists of $e + e'$ and the former area D now consists of the areas $d + d'$. The largest semicircle obviously is the sum of $T + e' + d'$. Since $e + e' + d + d'$ are equal to T

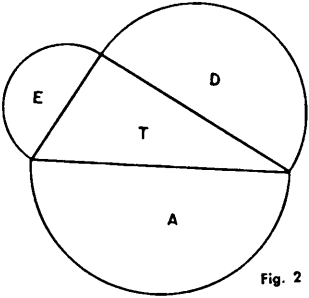
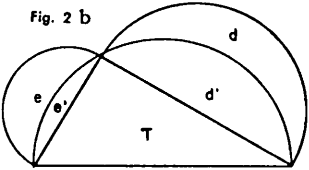


Fig. 2 a

Fig. 2 b



$+ \ e' + d'$, the area T must be equal to $e + d$. In words: the area of the two lunulae equals the area of the triangle. If this does not look like a possible approach to converting a circle into a square, nothing does.

The similarity can easily be carried a step farther by drawing the figure 3. The square inscribed in a circle demonstrably consists of four triangles; all you have to do is to connect the four corners by two lines which are also diameters of the circle. Then you construct the four lunulae. And there can be no doubt that $A = a$, $B = b$, $C = c$ and $D = d$. Of course A will equal d etc. etc. And $A + B + C + D$ equals the square.

All you have to do now is to convert the four lunulae into one circle and the problem is solved. But if you try to do that, you'll find out, after an hour or after three years, depending on your individual persistence, that it cannot be done.

The lunulae of Hippocrates are an interesting and very special

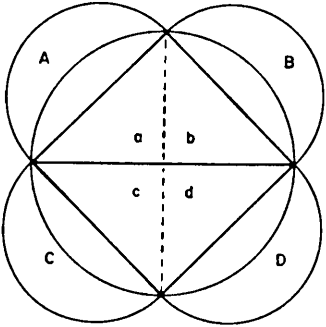


Fig. 3

case which only happens to look as if it bore any relationship to the problem.

BUT the whole thing, countless people have moaned through the centuries, looks so simple on principle! You can prove that a certain triangle *must* have the same area as a given circle. The height of that triangle must be equal to the radius of the circle and its base must be equal to its circumference. It remains to construct such a triangle. The height presents no problem, of course, but just what is the length of the base?

This problem has a separate name. It is called the rectification of the circle, but actually rectification and quadrature go hand in hand. If one could solve the one, the other would be solved automatically.

Well, the circumference of the circle is its diameter multiplied by something, namely the ratio of diameter to circumference. Everybody knows now that this ratio is called by the Greek letter *pi,* and since the problem came down to us from the Greeks, one has the tendency to assume that it was "always" called by that letter.

Actually the use of *pi* to designate this value is rather recent. It was used that way for the first time by the Englishman William Jones in 1706 in a book with the title *Synopsis palmariorum Mathesos,* which was an introduction to mathematics. Mr. Jones' usage was then popularized by Leonhard Euler in his voluminous correspondence as well as in his main work, the *Introductio in analysin infinitorum* which appeared in 1748.

The wrestling with this value goes back past the Greeks for good and practical reasons. The oldest figure we have is that given in the Papyrus *Rhind.* The copy of the papyrus we have is not the original; it says in the manuscript itself that it was copied by clerk Ahmes, the servant of the king Raaus, which dates the copy as having been made in about 1700 B.C. The papyrus states that the area of a circle is equal to a square constructed with the base of 8/9th of the diameter. In decimal notation, this makes *pi* equal to 3.1604, which is better than the figure given in the Bible (1 Kings, vii, 23 and 2 Chronicles iv, 2 if you want to check) where the value of *pi* appears as a straight three.

Among the Greeks, the first to come up with a value was Archimedes, who stated that the figure was greater than 3 10/71 but smaller than 3 10/70. Compared to the modern value, these figures look as follows:

3 10/71 = 3.14084
pi = 3.14159 . . .
3 1/7 = 3.14285

This is really good enough for most practical purposes and the value of 3 1/7 was used for many centuries for such things as measuring the iron rim for a wheel or cutting paving blocks for a circular enclosure of some kind.

ROMAN surveyors know Archimedes' approximation of 3 1/7, but are said to have used 3 1/8 in their work since it made calculations that much easier!

Of the Chinese, we know what values were used by some of their mathematicians, but we do not know how they arrived at them.

One Wang Fau used the ratio 142/45, which is 3.1555, while Chang Hing thought that *pi* was equal to the square root of 10, which is 3.1622777, an accidental similarity that has troubled many later circle squarers. (Another such similarity has caused many geometrical constructions, namely the fact that the square root of 2 plus the square root of 3 closely resembles *pi. The* figures are 1.4142136 + 1.7320508 = 3.1462644.) The best Chinese approximation was that of the astronomer Tsu Ch'ung-chih (born in 430 A.D.) who arrived at the ratio of 355/113 or 3.1415929.

Of the men of the Renaissance who tried their hand on the rectification of the circle, I'll mention only Nikolaus Chrypffs, who was born at Kues on the Moselle in 1401 and became known later in life as Cardinal Nicolaus Cusanus. His construction is shown in Fig. 4. If the smaller circle to the left is the given circle, you construct one side of the inscribed square AB and use this to establish point C. Then you draw a circle the center of which is halfway between point C and the center of the first circle. The triangle inscribed in this second and somewhat larger circle has the same circumference as the first circle. Or rather it would have if *pi* were equal to 3.1361.

A much better, slightly more accurate and at any event faster approximation is the one shown in Fig 5. The construction is obvious from the drawing. The line ABC, when multiplied by two, is a fraction of a per cent longer than the circumference of the circle.

The construction shown in Fig. 6 is even more elegant. It was found in 1685 by Adam Kokhansky, the Royal Mathematician of the King of Poland.

The construction begins with

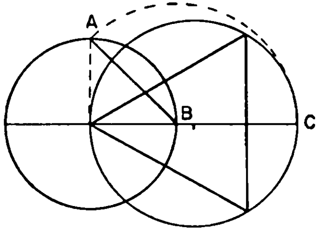


Fig. 4

the circle, a tangent and a diameter which touches the periphery in the same point as the tangent. Then you construct an angle of 30°, which establishes point A on the tangent. Then you proceed along the tangent for 3 radii, which establishes point B.

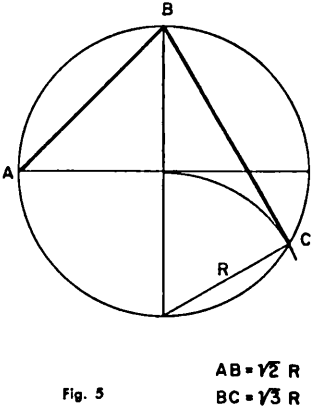


Fig. 5

The line from B to C represents half the periphery of the circle. It does so with surprising accuracy, for it would be correct if *pi* were 3.141533.

Actually, *pi* is a so-called transcendental number which cannot be expressed accurately either by decimals or as a fraction. Since this cannot be done, it cannot be constructed. You can produce almost any degree of accuracy you wish, but it cannot really be accurate — provided, to repeat, that you stick to compass and unmarked straight edge as the instruments employed.

BUT though most people know by now that a fully accurate construction is impossible, every once in a while somebody succeeds in coming up with a new approximation that has been missed in the past. In 1910, a German civil servant, Peter Pupovac, submitted to a mathematician the construction shown in Fig. 7. You divide the diameter of the circle into five parts, add one more and draw a vertical line in that point. You make it three divions high. The sum of the three sides of this triangle nearly equals the circumference of the circle, namely 6/5 + 3/5 + 3/10 multiplied by the square root of five. This amounts to 3.14164, so the sum of the sides of the triangle is 0.00005 diameters too large.

Another surprising approximation—this time a direct quadrature rather than a rectification—was found accidentally by a German officer in World War I. During a period of quiet in springtime, when the lilacs were in bloom, he amused himself by trying to draw a representation of a lilac blossom with nothing but a pair of compasses. When he had obtained a result which he considered a good representation, he

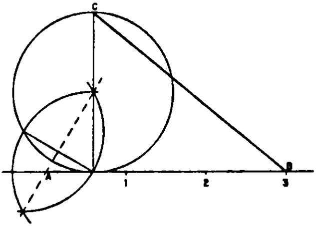


Fig. 6

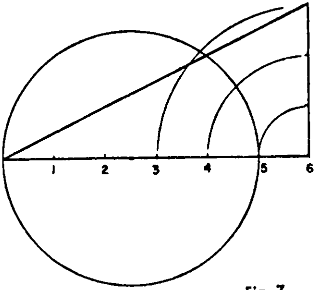


Fig. 7

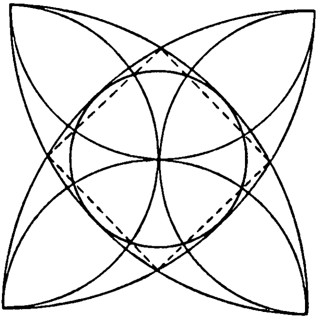


Fig. 8

noticed that a circle and a square overlapped. (Fig. 2) They looked as if they were equal in area.

After the war, he sent the figure to a mathematician, Dr. Theodor Wolff, with the question whether Nature might not have accomplished something that Man had failed to do. Dr. Wolff had a ready answer, namely that Nature, if she had found a solution, had done so in violation of the classical rule, something which Man could do, too. Then he calculated what mistake, if any, Nature had made.

Nature had not solved the problem even by using non-classical methods. The difference between the areas of the circle and the square is a little less than one per cent of the circle's area.

The savants of the French Academy who decided not to waste their time any more by examining so-called solutions of the circle-square problem would have liked this little touch. Even Mother Nature can't do it correctly!

—WILLY LEY