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For Your Information

By WILLY LEY

EARTH TUNNELS

I AM reasonably sure that most of my readers have never come across the name of Maupertuis. If you want to remedy this in a hurry, just reach for an encyclopedia—you'll find him listed as "Maupertuis, Pierre Louis Moreau de, (1698-1759), French mathematician and astronomer."

You'll find some remarks about his life, too: that his king (Louis XV) sent him to Lappland to measure the length of a degree of the meridian, and that he quarreled with Voltaire—as who didn't?—and was an able mathematician. Also it is stated that he was the author of a number of works such as *Sur la figure de la terre, Lettre sur la comète de 1742,* and *Astronomie nautique.*

All of which may tend to make you feel that Monsieur de Maupertuis may have been an important scientist in his time but not worth much type nowadays, beyond an entry in the encyclopedia.

BUT that is merely due to the fact that reference books often omit the really interesting things about people. Perhaps Maupertuis was excessively vain (at least all his contemporaries said that he was), and perhaps he was just a shade more quarrelsome than the other learned men of his time—but he was also full of amusing ideas and never hesitated to talk about them.

When, for example, his compatriot and contemporary George Louis Leclerc, Comte de Buffon, speculated about *Terra australis incognita,* the "Great Unknown Southland" which was then supposed to exist somewhere in the South Seas, Maupertuis jumped in without hesitation.

Buffon, in his speculations, had drawn a parallel to South America. Coming from the Atlantic Ocean, he said, one first encounters the South American lowlands, inhabited by primitive tribes—but farther inland, where the mountains tower toward the sky, there was an area where there had been a high culture with magnificent architecture. Similarly, in the South Seas, we had found only the low islands, inhabited by primitive peoples. So when we finally managed to penetrate to the hypothetical Southland—which was assumed to have tall mountains too—we'd probably find another strange and so far completely unknown culture.

Maupertuis agreed with Buffon so far as the idea of an unknown southern continent was concerned. He also subscribed to the assumption of high mountains in the unknown Southland for the simple (and to us surprising) reason that it was not at that time known how an iceberg is formed: it was thought that icebergs formed in rivers only—hence there had to be enormous rivers to produce the icebergs which had been seen. And the large rivers, in turn, demanded high mountain ranges to supply them.

But there Buffon and Maupertuis parted company. Maupertuis did not expect to find a high culture in the Southland—or any culture at all! The culture of the Andes was high, he admitted, but from there on things went downhill. The islands in the Pacific had a lower and lower culture the farther one went, so obviously none was left for Southland itself—its inhabitants probably still had tails! All this was proclaimed, without any unnecessary hesitation, at Castle Sanssouci near Potsdam, at the dinner table of Frederic the Great.

Many years later, French and German explorers might add deadpan to their reports that the natives were tailless . . . to the puzzlement of readers who did not know just what this was about.

MY MAIN reason for telling about Maupertuis, though, is that he is the father of an idea which has been repeatedly used in science fiction. He "invented" the tube through the center of the earth.

Just what would happen if one had a truly bottomless well?

Maupertuis was, as has been said, an excellent mathematician. He was also one of the men of science who accepted Sir Isaac Newton's teachings wholeheartedly. The problem of the bottomless well became an exercise in mathematics.

Obviously, if you fell into such a well, you'd fall faster and faster until you reached the center of the Earth. But you would not stop there, of course, for by that time you would have acquired a considerable speed, and would continue to "fall upward" through the remaining half of the well. Gravitation would slow you down to zero at the precise point of reaching the surface at the other end of the bottomless well—and your assistant at the other end could yank you sidewise onto solid ground, before you had time to start falling again. The trip—and the trip back, if you had no assistant—would take 84 minutes and 22 seconds. The speed would be highest at the Earth's center, where it would be (expressed in our measurements) five miles per second.

Of course, the bottomless well would have to be evacuated, so that the traveler would not be slowed down by air resistance. And the whole thing would work even better only if one first stopped the rotation of the Earth, for lacking that, one would have to dig the well from pole to pole.

But in the pole-to-pole connection itself there is some hidden trouble: the area of the South Pole is about one mile above sea level, while the area of the North Pole is virtually at sea level. So if you try it from north to south, you don't quite reach the other end, which is one mile above your farthest point. And if you go from south to north, you reach north polar sea level with enough residual velocity to rise one mile into the thin air!

So you might spend some time in such a tunnel . . .

Just about half a century ago, a Russian writer by the name of A. A. Rodnych (who later acquired fame as a historian of aviation) demonstrated that Maupertuis, and after him Camille Flammarion, had failed to extract *all* the humor from the idea. There was still a trick left —and Rodnych described it under the title: *Subterranean self-propelled railroad between St. Petersburg and Moscow; Fantastic Novel, for the Present in only three and moreover incomplete chapters.*

The point was very simple: there are no straight tunnels. If there were, you would not need fuel.

Suppose a perfectly straight tunnel were built from Kansas City to San Francisco—straight enough to look through, even though you might need a telescope to make out the light from the other end. This tunnel would be straight, but *not* horizontal: its center would be closer to the center of the Earth than its two ends. Hence, from whichever end you enter, you go down. A railroad car on a track through the tunnel, with its brakes released, would begin to roll. Just as in the bottomless well, the speed would increase and increase until the center of the tunnel was reached, at which point the direction would be "up" and the speed would begin to decrease. And *if* there were no friction in the bearings and on the rails, and no air resistance (and also if the wheels could stand the speed near the center without being torn apart by centrifugal force), the railroad car would reach the other end of the tunnel with zero speed and without having used a drop of fuel. Provided, of course, that both tunnel mouths are the same distance from the center of the Earth, i.e. same elevation above sea level.

The timetable for such a railroad would not pose any problems: each and every train would arrive at its destination precisely 42 minutes and 11 seconds after its brakes had been released at the other end . . . whether the tunnel was 1000 miles or a mere 100 miles long.

SINCE we are talking about gravity, let's consider the case of the young man whose chair simply moved across the polished hardwood floor until it was next to that of the beautiful brunette —and who explained it by "attraction" and blamed it all on Sir Isaac Newton.

Since I happened to be around, I was called upon to testify that Newton actually had said that each particle of matter in the Universe attracts every other particle. True, he did say that . . . but if I had been the young lady, I would have protested bitterly at the implication that I weighed several times as much as Mt. Everest.

Seriously: some people do wonder why the law of universal gravitation is not noticeable in daily life. Science says that all bodies attract each other, but most of the time it certainly doesn't look that way. On the other hand, when two ships collide in a fog there are always some people who believe that Newton's law was responsible. To get the matter straight, we obviously need some figures:

If we have two pieces of matter, each weighing one gram, and they are one centimeter apart, what is the attraction between them?

Answer: about 1/15,000,000 milligram.

One milligram, of course, is the thousandth part of a gram, and there are 28 grams in an ounce. If one of the two pieces of matter weighed 5 grams and the other 8 grams — and they were still one centimeter apart— their mutual attraction would be 5 x 8 or 40 times as large as that of the two one gram pieces. But if they were three centimeters apart, you'd have to divide the attraction over the standard distance by 9 to get the proper figure.

A nice big orange weighs about 200 grams; two of them almost make a pound, since a pound is equivalent to 450 grams. If we place two such oranges ten centimeters or just about four inches apart, their mutual attraction then is 200 x 200 = 40,000 divided by 10 times 10, which gives 400 as the result. This result has to be multiplied by 1/15,000,000, the final result being 4/150,000 or not quite 1/40,000 milligram. This, quite evidently, is far too little to be noticeable or even measurable.

As for the young man and the beautiful brunette, their mutual *gravitational* attraction must have been about 0.03 milligrams if they were originally 100 centimeters (about forty inches) apart. But the friction of the chair on even the best polished hardwood floor must have been well over twenty pounds—so I'm afraid we must assume that some other kind of attraction was responsible for that particular phenomenon.

How about something that is really heavy, though — say a middle-sized ocean liner of 25,000 tons weight?

Since ocean liners as a rule avoid close contact, we'll say that they float 100,000 centimeters (6/10th of a mile) apart. Making the same calculation as before, which is multiplying their weights in grams, divided by the square of their distance in centimeters and multiplied by the constant for one gram at one centimeter, we find that the liners would attract each other with a force of 4.2 grams. Even if they were only a hundred yards apart, the attraction would amount to just about one pound — hardly enough to move a ship. So when two ships collide in a fog, it just means that they happened to be on a collision course.

The figures show why the mutual gravitational attraction of masses does not show in daily life. It becomes important only if one of them is of planetary size—for example when the man on a slippery floor is attracted by the Earth.

MORE PRIME NUMBERS

NO other item in my column has brought in such a large volume of mail as my piece on prime numbers in the June 1953 GALAXY. Since more than a score of letters and postcards—22 by actual count, at the moment of writing—queried the expression on p. 70, I'll begin the discussion with that.

Of course, as eleven correspondents stated or at least suspected, Fermat's expression suffered from a typographical error. The exponent of the "2" is *not* 2n but 2^n, so that the expression reads correctly

$$2^{(2^n)}$$

The five readers who amiably called me a bungler and ignoramus will please air their grievance with the typesetter; my copy was correct, and I have a carbon copy of the article to prove it.

Another twelve letters dealt with a fact beyond my control, but one which I also regret. About a month after my article was written, the NBSINA (National Bureau of Standards Institute for Numerical Analysis) on the premises of UCLA (University of California, Los Angeles) announced that SWAC (Standards Western Automatic Computer) had established higher Mersenne primes than the famous $2^{127} - 1$. The list of higher Mersenne primes reads as follows:

$2^{521}-1$
$2^{607}-1$
$2^{1279}-1$
$2^{2203}-1$
$2^{2281}-1$

One Canadian reader thought that he had found a proof of Goldbach's theorem. His reasoning was as follows: disregarding the 2, which is the only even prime, a prime number must of necessity be an even number plus one: $P = E + 1$. Hence, if you add two primes p_1 and p_2 you really add $E_1 + E_2 + 2$ which obviously must be an even number since you add three even numbers together.

Now this is proof, if one were needed, that the sum of two primes must be an even number —but this is not what Goldbach said. Goldbach stated that every even number is the sum of two primes, which sounds like the same statement, but actually is not.

To explain the difference, let us assume that Goldbach's theorem is wrong. In that case, there should be at least one even number which is not the sum of two primes but merely the sum of two odd numbers, either of which, or both, are not primes. The proof to be found, therefore, is that there is *no* even number which cannot be expressed as a sum of two odd numbers *both* of which must be primes.

Among the correspondence there were several letters asking me for a list of primes up to certain limits or asking where such a list can be gotten. I don't know whether the list can still be bought, but it should be in any reasonably large public library. Its title is *List of Prime Numbers from 1 to 10,006,721* by D. N. Lehmer; it is a publication of the Carnegie Institution of Washington, Publication Nr. 165, released in 1914. The recent work on the big Mersenne primes can be found in *Mathematical Tables and Aids to Computation,* Vol. 7. p. 72 (1953).

—WILLY LEY

ANY QUESTIONS?

Will you please tell me how to determine the acceleration of a rocket if its weight and thrust are known? In space, would the weight of a rocket affect its acceleration in any way?

Richard Weed
201 Harper Avenue
Morrisville, Penna.

The formula for determining the acceleration of a rocket is about as simple as a formula can be. It is P/W, where P stands for the thrust and W for the weight. In practical application, however, there are some minor complications which

have to be taken into account, one of which is the direction of the movement.

Let's assume that the rocket has just taken off and is moving vertically upward. We'll say that its weight is 100 lbs. and that its rocket motor develops a thrust of 300 lbs. 300 divided by 100 is, of course, 3—so the rocket's "absolute" acceleration would be 3g.

If this were the whole story, it would mean that the rocket is climbing at 3g (or accelerating 96 feet per second), so that at the end of each second of flight its velocity would be 96 feet per second faster than at the beginning of that second. But (obviously) if the motor were not working, the rocket would fall back—which is to say that the Earth's gravity swallows up one g of the "absolute" acceleration. Hence the "effective" acceleration is 2g, and the formula has to be amended to read P/W—lg. The interesting point here is that, if the rocket is manned, the pilot feels the *absolute* acceleration while the speed increases according to the *effective* acceleration.

The "true" effective acceleration is influenced by air resistance, which will vary with the speed of the rocket at a given moment and its altitude (or more precisely the density of the air at that altitude). As important as that is the fact that the weight of the rocket at the end of that second will be less than the weight at the beginning of the second.

All this applies to empty space too, except that (a) there will be no air resistance, (b) the value for the thrust is about 15 per cent higher than the sea level value of the same rocket motor and (c) at a sufficient distance from the Earth the value for g may be noticeably less than the sea level value. For a height of 250 miles, for example, g has dropped from about 32 ft/sec^2 to 28.5 ft/sec^2.

Does a rocket which takes off toward the west have to attain a higher velocity relative to a point on the ground to reach orbital velocity than a rocket headed east?

William J. Hunt
2325 *NE* 32*nd Avenue*
Portland 12, *Oregon*

Let's take this one step by step.

In von Braun's orbit—1075 miles above mean sea level—the rocket will have to have a velocity of 4.4 miles per second. If it has that velocity in the orbit, it doesn't matter whether it goes around the equator heading east or heading west, or along a meridian from pole to pole, or at any odd angle in between.

Repeat: If it has that velocity in the orbit . . . but first it has to *acquire* this velocity.

For simplicity's sake, let's suppose that take-off is at the equator. The equatorial diameter of the Earth is almost 8000 miles, hence the length of the equator is that figure multiplied by "pi" or, in round figures, 24,000 miles. Since the Earth turns once in 24 hours, a point at the equator moves in an easterly direction at the rate of 1000 miles per hour or about 0.28 miles per second.

So if your rocket heads east it has, relative to the center of the Earth, a speed of 1000 miles per hour before it even starts. If you wanted to head west, you would not only lose that 1000 mph, but you would have to "kill" it first—so that you lose 2000 miles per hour, or around 0.56 miles per second. Half-a-mile a second is a considerable speed, even for a rocket, so take-off in an easterly direction is usually assumed.

What does the term "Doppelgänger" mean?

Cpl. D. A. Freeman, USMC
Fleet Post Office
San Francisco, Calif.

This is originally a German word, composed of two words each of which is hard to translate—which is, of course, the reason why it was adopted rather than translated.

"Doppel" can mean "twice," and also "double" (the amount) or "duplicate."

"Gänger" is best translated as "walker."

The whole means: "a walking duplicate."

The superstition attached to the word is that some people have such a "duplicate" walking around, and when they meet it face to face they know that they are doomed, with usually only three days of grace left to them. But in everyday German conversation, the term "Doppelgänger" can be and often is used without mystical connotations. A man saying to a friend, "I met your Doppelgänger today," merely means that he met somebody or saw somebody who looked just like his friend.

Why is the nautical mile longer than the ordinary mile? Is there any relationship between the nautical mile and the metric kilometer? And is there such a thing as a "metric mile"?

James A. Monahan
(no street given)
Chicago, Illinois.

If anybody knows the origin of the English mile, I wish he'd write me, for as far as I know the mile—1760 yards or 5280 feet long—is a unit which just happened.

The nautical mile, however, has a reason; its length is 1/60th of one degree at the equator.

As for the kilometer, it also has a reason: it is 1/10,000th of the distance of a point on the equator from either pole—Or rather it is supposed to be, for more recent measurements have shown a small deviation from that figure.

There is no "metric mile"; but for a while geographers used a unit which they called the "geographic mile," which corresponded to 1/15th of a degree at the equator.

The various "national" miles are as uncertain in origin as the English mile, though some of them happen to come fairly close to the old geographic mile. To compare them, the kilometer has been used as the unit in the following table:

1 English mile	1.609 km.
1 nautical mile	1.852 km.
1 geographic mile	7.420 km.
1 German mile	7.500 km.
1 Danish mile	7.582 km.
1 Swedish mile	10.688 km.
1 Norwegian mile	11.295 km.

The Russian *verst* measured 1.066 kilometers (or 0.6629 miles), but like all the other old miles given, it is now obsolete. The only units in use internationally now are the kilometer, the English mile, and the nautical mile; but the French nautical mile is three times as long as the nautical mile of everybody else. Don't ask me why.