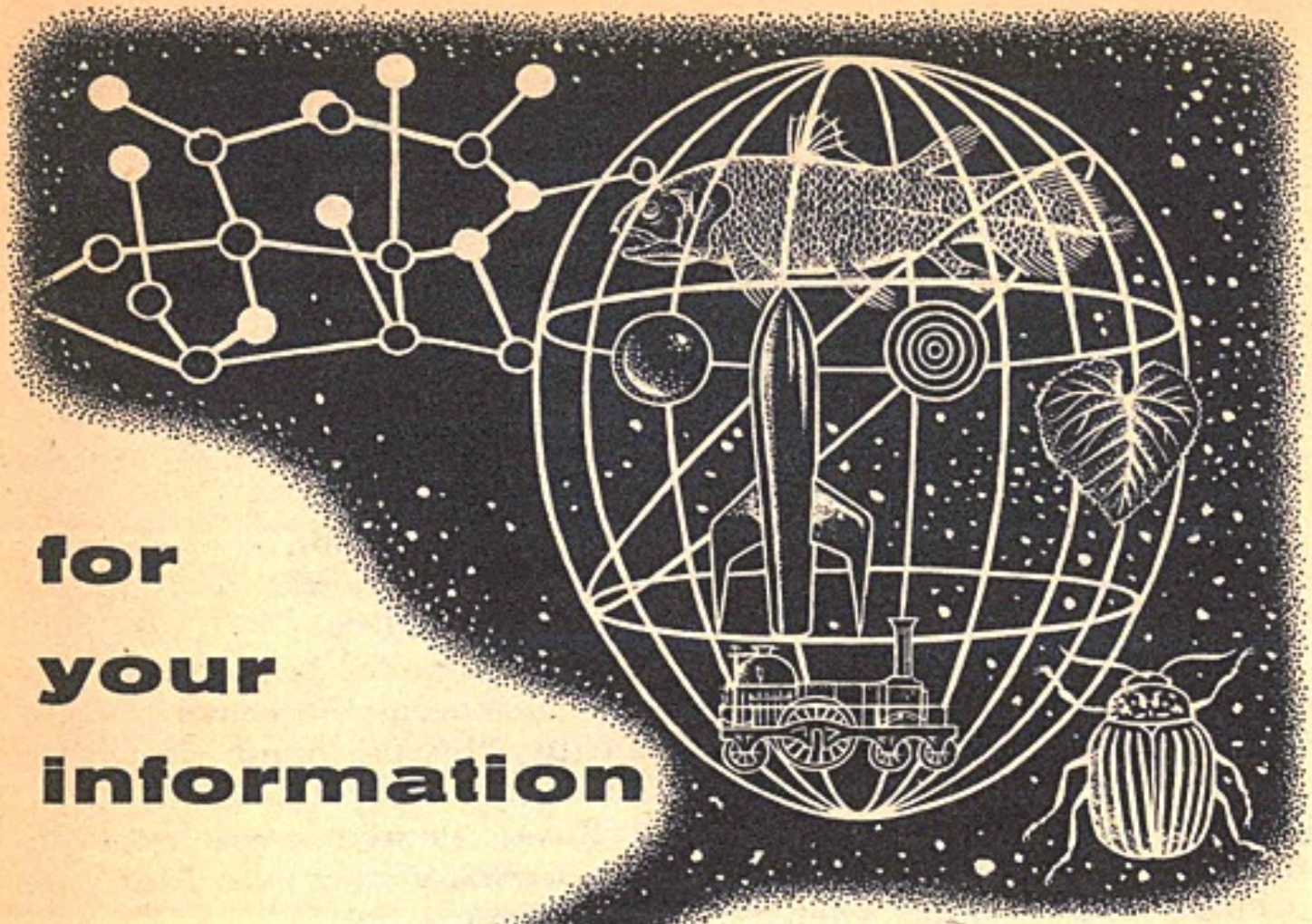

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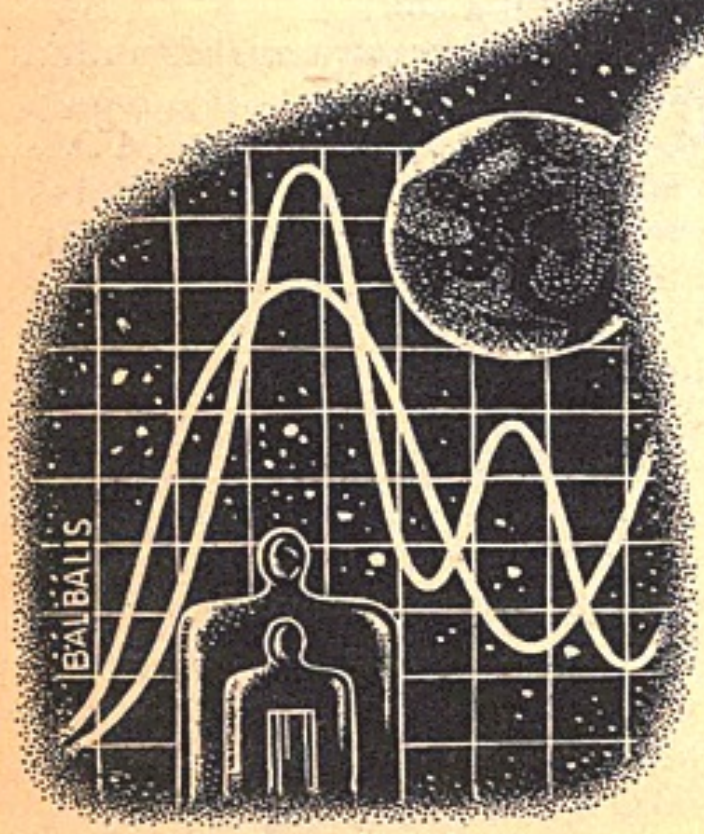

BY WILLY LEY

LET'S DO SOMETHING ABOUT THE WEATHER.

JUST seventy years ago General Robert Dyrenforth traveled from Washington, D. C., to Texas to spend nearly $9,000 on gunpowder and high explosives. He was not heading a military expedition of some kind and the powder and explosives were not expended against outlaws, Indians or Mexicans. This was research for which Congress had appropriated the sum mentioned. General Dyren-

forth by that time was no longer an active military man but represented the Department of Agriculture. And the explosions were set off to influence the weather, to cause rain if it could be done. It was the first instance of large-scale research on weather control.

Did it work?

It did rain occasionally after a few barrels of gunpowder had been set off. But if some Texan who stood around and watched the activities claimed that it would have rained anyway, there wasn't much General Dyrenforth or anybody else could say in reply. The increase in rainfall was not decisive.

The whole experiment had been an outgrowth of a story, revived by the Civil War, that had started in Europe a century or so earlier. Veterans of the Seven Years' War told anybody willing to listen how every big battle had been followed by a downpour. After the Napoleonic wars the story was revived, and again after the Civil War in the Western Hemisphere.

By 1869 an American engineer by the name of Powers decided to collect all stories of this kind — of course not all the stories were purely military; some of them related to rains following the accidental explosion of powder magazines — and to check on their accuracy as far as this could be done. Powers was so convinced that the stories were accurate that he titled his book *War and Weather*. It appeared in 1871 and was the ultimate reason for the appropriation of $9,000 to the Department of Agriculture.

POWERS' book was not the first work to say that human activities, voluntary and involuntary, influenced the weather. In 1841 another American, James Pollard Espy, had published a book with the title *Philosophy of Storms*. In this book he explained that rainfall was often caused by large fires, as for example forest fires. He reasoned that the air heated by the fire would rise, other air had to rush in laterally, and a fire which lasted for some time would therefore produce convection currents leading to the formation of cumulus clouds from which it would rain. It should be said right now that this does happen, but not every time.

The adherents of the "gunpowder theory" did not claim that explosions caused the clouds but felt that the shock waves caused by the explosions induced the clouds to shed their moisture. At a later date this theory was somewhat amended by saying that the solid particles released into the atmosphere in the form

of smoke acted as "condensation kernels" on which the water vapor of the clouds could condense.

Parallel with the belief that the gunfire of a battle caused rain to fall, another belief grew up which does not seem to have made its way to the New World and which cannot be traced in detail even in Europe, where it was confined to the countries to the north of the Alps. That was the belief that shooting, even if it did not produce rain, at least would prevent hail. Many townships, especially in agricultural regions, bought cannon and held them ready to fire oversized charges but without projectiles whenever a cloud which looked as if it might ruin the crops with hail appeared in the sky. Whether it actually did any good is doubted by all meteorologists, but at the time it certainly looked as if it were effective. In the first place, not every black cloud is a hail cloud. In the second place, the hail cloud might sail on, and who cared about hail in the next region? In the meantime the hail cannon got all the credit.

To return to scientific reasoning: during the period from, say, 1875 to 1890, it was realized that some cooling effects in the clouds must have had something to do with the onset of precipitation. Well, if such was the case it might be possible to help the cooling along. Somebody by the name of Louis Gathmann is on record as having been the first man to suggest (in 1891) shooting liquid carbon dioxide into reluctant rain clouds.

THERE are scattered records of some early experiments with what we now call "cloud seeding" performed prior to the First World War. Each and every one of these experiments seems to have been severely underfinanced and none of them was conclusive. Besides, the experimenters did not yet know the necessary details; modern cloud seeding looks for clouds which are already supercooled and just tries to trigger them. The early experimenters apparently tried to make clouds by cooling the air with their carbon dioxide or liquid air. It isn't completely impossible that this may be made to work, but it would require enormous quantities of cooling agents, and if it could be made to work, it certainly would not pay.

The first modern experiments along those lines were performed in 1930 in Holland by Augustus W. Veraart and they do sound "modern." To begin with, he used an airplane. And he seeded clouds with "dry ice" and with a mixture of "dry ice" (frozen carbon dioxide) and supercooled normal

ice crystals. While the experiments themselves were quite scientific, Veraart's presentation of them apparently was not. He is said to have made such exaggerated claims that he annoyed people just by the way he made them. At any event the Royal Dutch Ministry of Agriculture as well as the Royal Dutch Meteorological Society publicly washed their hands of the whole affair, with the result that other researchers did not even bother to read Veraart's articles, which were written in Dutch.

There followed some theoretical work. In 1933 the Swedish meteorologist Tor Bergeron stated that it should be possible to release rain from existing clouds by introducing ice crystals into them. Five years later the German physicist Walter Findeisen went over the problem mathematically and especially emphasized the need for the natural presence of supercooled water droplets while the ice crystals were being introduced. As often happens in science, Bergeron's and Findeisen's works were later lumped under the name of the "Bergeron-Findeisen Theory" which makes it sound as if they had cooperated in the formulation.

The next chapter in the story bears the name of a company: General Electric. It was one of those stories which would sound pretty weak if it were fiction, but in reality things happen that way sometimes. It began with a request by the Chemical Warfare Board to find out just how the filters in gas masks do their work.

General Electric's chief scientist, Dr. Irving Langmuir, assisted by Dr. Vincent J. Schaefer, went to work. Now if you want to test filters, you must test them on something. So Langmuir and Schaefer started producing all kinds of "smokes," which led to research on smoke screens in all kinds of weather. Cold-weather research prompted them to investigate aircraft icing. The icing of an airplane wing obviously builds up from particles in the cloud, hence the next point was to investigate how ice particles in clouds grew.

SCHAEFER found that crystals of dry ice did cause supercooled clouds (small laboratory type) to form water ice crystals. Bergeron and Findeisen had been right. The next problem was somewhat different. The tiny ice crystals would stay aloft with the cloud. Would they grow large enough to fall out of the cloud, melting into raindrops before they hit the ground? This had to be tested in the open and in November 1946 Dr. Schaefer started scattering dry ice pellets

into clouds from above. Yes, the ice crystals did grow large enough to fall from the cloud.

Soon afterward another researcher, Dr. Bernard Vonnegut, discovered that microscopic silver iodide crystals — one of the "smokes" that had been made — were more efficient than ice or dry ice. For some reason silver iodide crystals will cause ice to form at higher temperatures than either dry ice or water ice.

Once it had been established that something could be done, several branches of the government started specific projects. One was Project Cirrus, paid for by the Army and Navy with airplanes supplied by the Air Force. Another was the Cloud Physics Project, sponsored by the Weather Bureau, the Air Force, the National Advisory Committee for Aeronautics (NACA, now NASA) with Navy equipment. Then came the Department of Defense's Artificial Cloud Nucleation Project.

The result of all this work can be summed up in one sentence: You can make it rain if the right kind of cloud is available.

A hundred years ago this would have been acclaimed as a fantastic achievement. But now you hear voices saying, "Is that all? Can't we *really* do something about the weather? Can't we at least prevent or stop a hurricane?" And you hear complaints like, "Why doesn't anybody think big any more? Why don't they try to melt the polar icecap? It would be so simple. And whatever happened to the suggestion by the Russian fellow who wants to put a ring around the Earth like that of the planet Saturn?"

As for hurricanes, a big research program is on the way. Before anybody can suggest what might be done, he has to know with as much detail as possible what is going on. No doctor can prescribe a remedy or a treatment if he does not know what is wrong with his patient. The medical comparison may be unjust, but one of my teachers (the professor of zoology who had started out as a medical student) told us with a smile that when he was a student his teacher faced a medical riddle. There were elderly people among his patients, married for 30 years or more, having slept in the same double bed all these years. One was sick, the other was not: *why didn't they infect each other?* The answer, to us, is quite simple: the patients were diabetics!

What I mean to say is that we haven't really diagnosed a hurricane yet. That nothing can be done about one which is in force is clear — the Weather Bureau estimates that a full-fledged hurricane develops about

the energy of ten plutonium bombs per second. But once we know enough, we might be able to prevent one from developing. Or it might be possible to deflect one into areas where it will do the least harm.

NOW let's have a quick look at the "big thoughts," beginning with the arctic icecap. Ice and snow reflect sunlight well — they have, to use astronomical language, a very high albedo. If you dusted the ice over with something dark, like coal dust, the albedo would be very strongly reduced, the sunlight of the arctic summer would be utilized and the ice would be melted. Let us assume for a moment that it could be done, all climatologists, meteorologists and a good number of economists would form a united front saying that it cannot be taken for granted that this would be a wise and beneficial move.

We don't have to worry about the wisdom, however, because Dr. H. Wexler, director of meteorological research of the U. S. Weather Bureau, indulged in a little arithmetic (*Science*, Oct. 31, 1958) running as follows. The layer of coal dust would not have to be thick to do its job. One-tenth of a millimeter would prabably be enough. But the total area of the arctic ice pack north of latitude 65°N. and of the adjacent snowfields is $24 \cdot 10^6$ square kilometers. This calls for 1500 million tons of coal dust. Using C-124 Globemasters which could carry 10 tons per sortie, it would take 150 million sorties to lay down the absorbing layer. Naturally this would take a little time to do and in the meantime there should be no winds to interfere with the experiment and, of course, no fresh snow must fall on the areas already dusted, which is also difficult.

The idea published by some Russian about a ring around the Earth has precisely the same set of drawbacks. If the Earth had a ring like Saturn, the arctic and antarctic nights would be illuminated and somewhat warmed. In fact, no night would ever be completely black again; there would always be about as much light as would be shed by half a dozen full moons. Unlike the natural ring of Saturn, the artificial ring should be inclined to the equator; an inclination of about 45° would probably give the best results if the lessening of polar winter nights were the main objective. Whether this would do more good than harm is again a question we can't answer yet. Nobody can say at the moment what this steady influx of additional if reflected sunlight would do to the Earth's climate in general.

SUPPOSE it were mainly good, what are the logistics of the operation? I don't know the Russian figures; I don't even know whether any figures were published. Therefore I had to devise my own. I assumed that the ring would start 1600 kilometers (1000 miles) above sea level and that it would be 1000 kilometers (about 600 miles) wide. I assumed a thickness of one kilometer mostly for the reason that it would be very hard to make it any thinner. That all this is in the area of the inner Van Allen belt is relatively unimportant; the rockets which lay down the ring do not have to be manned. The material would best be ice crystals (Saturn's natural ring mostly consists of ice crystals, too) since they reflect the sunlight well and do not cost much.

The area of the ring then becomes in round figures 53 million square kilometers. Since it is assumed to be one kilometer thick, its volume is the same figure in cubic kilometers. If we allot one milligram of water per cubic meter of ring volume, the calculations become quite simple. One metric ton (2204 lbs. if you insist on the measurements of the old merchant guilds) weighs 1000 million milligrams. And one cubic kilometer contains 1000 million cubic meters. Making the ring, therefore, requires as many tons of water as its volume in cubic kilometers: 53 million metric tons.

But since a milligram of water in the form of ice crystals can form more than one crystal, we might be able to cut down the necessary weight somewhat. Let's have just one ice crystal per cubic meter, instead of a milligram of ice crystals for that volume. If we say that each crystal, on the average, would weigh one-tenth of a milligram, the total amount of water would drop to 5.3 million tons. If, with super-accurate guidance, the ring can be made half a kilometer (a mere 1640 feet) in thickness, we need only 2.6 million tons.

Had enough of big thoughts?

Of course we still should try to do something about the weather. But first we have to learn much more about it.

ANY QUESTIONS?

Do meteorites hit the Moon? If so, why is there no evidence? Astronomers have assured me that, so far as we know, meteorites must hit the Moon at about the same rate (allowing for the smaller size of Luna) they hit the Earth. But if they do, they should pockmark the surfaces of the maria with craters; they should also stir up dust or pumice clouds momentarily. In either

case we might not be able to see the impact but we should see the result. When the Moon is dark, the smash of a meteorite on stone should certainly set up a spark of light which would be visible (comparatively speaking) as a match lit a long way off on a dark night. Finally it seems reasonable that, at one time or another, since Galilei, the Moon must have been clobbered by a big meteor on the facing side. This would leave a new crater . . . but apparently no change in the Moon's surface has ever been discovered. Can you explain this odd situation?

Boyd Hill
Playa del Rey, Calif.

Well, I can try to explain it. But before I go on, I want to go on record that this reply is being typed on August 10, 1960, just in case the Moon is struck by a colossal body the next day and the whole answer becomes negligible, superfluous and obsolete.

First let us be clear about one point. The gravitational field of a planet (or large moon) is of very minor, if any, importance with regard to the number of meteorites striking it. The meteorites are simply in orbits around the sun and sometimes a planet and a meteorite happen to be on collision courses. The gravitational field of the Earth might help in changing an "almost collision course" (near miss of a quarter-mile) into a collision course, but that is all.

Therefore, in a comparison between the number of solid particles which either the Earth or the Moon will sweep out of space, we don't have to wonder about the comparison of their gravitational field. All that counts are their cross sections — the size of the "target," so to speak.

The Earth's diameter is about 7950 miles, that of the Moon about 2160. The area of "Target Earth" is, therefore, a little more than fourteen times that of "Target Moon." All you have to do is to compare the squares of the diameters, or of the radii. Since we know, or can estimate, the number of particles swept up by the Earth, the number swept up by the Moon would be about 1/14th of the figure for the Earth. But since we can see only about one-half of the lunar surface, the number of impacts that might be seen would be only 1/28th of what we get for the whole Earth. To simplify life a bit, let's say that the Earth will sustain 30 times as many hits as the visible hemisphere of the Moon.

No actual count of what hits the Earth is possible, but the generally accepted estimate is a total of 7500 million particles during a 24-hour period. Of this

number about 6500 million particles have a diameter smaller than half a millimeter. Some 20,000 per 24-hour period will have a size of half an inch or larger. Half a dozen will be fist-sized or even larger. What our Earth sweeps out of space in the course of a day has been labeled "a very large dump truck of dust with a few pebbles in it."

How will this look to an observer? Well, everything smaller than one millimeter in diameter will simply be invisible. The ones one millimeter in diameter could be made out as a faint "shooting star" on a dark night. Those which are larger than an inch will be "rather bright," while those of the size of a man's fist would light up the landscape as they pass overhead.

Offhand, I would guess that a meteorite which hits the Moon would have to weigh at least 25 pounds to make an impact that could be seen from Earth if it hits the dark portion of the Moon and if somebody happens to be looking through a reasonably powerful telescope. Earth may collect one per month, which means that the visible portion of the Moon would collect one every three years. But remember the other requirements: somebody would have to look through a telescope at the dark portion of the Moon (which is not too customary) at the right time. Still, every once in a while an observer has reported a spot of light; in some cases it might have been a meteoric impact.

Not even a 50-pounder would produce a crater which would be visible from Earth, even through a powerful telescope. We don't know just how much would be needed, but the Russian payload that did hit the Moon gives a basis for a few guesses. The weight of that payload was around 800 pounds and the Russians fired for the center of the visible half of the Moon. Naturally they timed their shot so they would be able to observe the impact — of course when they have night, we have daylight. They claim they could observe the dust cloud caused by the impact. They calculated that the impact of the lunar probe itself would have caused a crater 600 feet in diameter and the impact of the top stage of their rocket a crater 850 feet in diameter, provided they struck a thick dust layer. For striking solid rock, the crater diameters would have been 33 feet for the probe and 50 feet for the rocket. They must have struck solid rock, because so far no photographs of the two new craters could be produced.

Since small lunar formations are pinpointed by their shadows at sunrise and sunset rather than

by direct visibility, the failure to find the impact craters of the Russian moonshot is not surprising. At the very best they would be at the limit of detectability, if they had struck in an otherwise featureless plain. Obviously they did not. Equally obviously a 1000-pound meteorite would not produce a conspicuous crater.

One more point to be considered is the question of for how long we have good lunar maps. We can't count from the invention of the telescope — some of the names proposed by the Italian Riccioli for lunar formations are not in use now for the simple reason that modern astronomers are not sure just which formations Riccioli had in mind. We can say that we have maps which might be good enough to help in spotting a new crater for only the past 80 years. It is easily possible that nothing big enough struck the Moon on the visible hemisphere during that time.

On Earth we had two known meteorite falls of sufficient size in this period, both striking in Siberia. One was in 1908, the other a dozen years ago. (Of course a few more big ones might have fallen into the oceans, or in Greenland, or in Antarctica, though no trace has been found.) But considering the ratio of about 30 to 1, it isn't at all surprising that no new crater has appeared on the Moon during the last 80 years.

Why wouldn't it be a good idea to build some sort of catapult for getting our larger rockets off the ground?

(Name withheld)
San Francisco, Calif.

I am withholding the name because I had to reply to my correspondent that (A) it is not a good idea, that (B) I get this question about once a week and that (C) the Space Agency (NASA) gets it twice a day, if not more often. This constant stream of the same question has, incidentally, been reinforced by some magazine writer who claimed to know that this was the way the Russians got their satellites into orbit. I may insert here that it is just possible that this is one more of the many translators' mistakes which have been plaguing us recently. The Russian word for catapult is the same as ours (it is one of those international words which are the same in most languages, like "radio," "airplane," "transistor" and so forth) and it is conceivable that the word is applied to a booster rocket.

But I still have to explain why it is not a good idea.

If you want to accelerate a rocket initially by means of a

catapult, you deal with several factors. The first one is how fast you want your rocket to be going at the instant it leaves the catapult; or, phrased differently, how much velocity you want the catapult to supply. The second factor is the length of travel of the catapult — through what distance does it move? Both these factors together tell you what the acceleration will have to be.

Now the solid-fuel booster of the old Aerobee rocket supplied just short of 1000 feet per second, or 300 meters, since 300 meters equal 984 feet. To supply any less than this velocity would not be worth the effort, so let's stick to this figure.

The three factors in question are tied together by the simple equation: $a = v^2/2s$. In this equation "a" stands for the acceleration which will result, "v^2" is the square of the velocity desired, while "s" is the distance traveled in the course of producing the desired velocity. Now let us check the values with this velocity in mind. First doing the righthand portion of the equation, we have to assume a value for "s" and for a first attempt we make "s" equal to 984 feet too, or 300 meters. Then $v^2/2s$ reads 90,000 divided by 600, which is 150. This figure stands for the mean acceleration the rocket would have to stand. One g in the metric system is 9.81 m/sec^2 so that this figure of 150 means just about 1-1/2 g.

Well, this is fine. The rocket will be able to stand an acceleration of 1-1/2 g. Yes, but no catapult is a thousand feet tall. In reality we'd probably have to be satisfied with a hundred feet, in which case our rocket would have to undergo an acceleration of 15 g. Some of the smaller solid-fuel jobs might be able to take this without being deformed (and blowing up) in the process. But a liquid-fuel rocket just could not stand this acceleration, and certainly not a big one.

So things boil down to the following choices: You provide only 100 or 200 feet per second. In this case it isn't worth the trouble. Or else you strengthen the rocket to withstand the high acceleration, in which case you have more dead weight in the rocket itself and you pay a higher penalty for the dead weight than you gain by even a thousand feet per second.

With all this we haven't yet touched another point, a rather sore one, namely the expense of the catapult — and its own weight. If you want to help an Atlas off the ground, you have to accelerate (in round figures) 100 tons. The moving portion of the catapult would have to weigh at least 10 tons. And you have to move these ten tons too. This

will cost fuel of some kind. The same amount of fuel will do more good if it is incorporated in the rocket itself — and you save the price of the catapult.

For the Puzzle Addicts

I AM sorry I forgot to give the explanation (as quite a number of readers reminded me) of the problem of the two Dutchmen with only one bike. What you need here is not mathematics but logic. No matter how the course is broken up, each one gets to ride a total of half the total distance. So, obviously, they save travel time — as one reader proved by the use of integral equations.

Now here is another one, cribbed from a friendly European magazine the name of which will be revealed with the answer in the next issue. The sequence of the first nine whole numbers is, of course, 1, 2, 3, 4, 5, 6, 7, 8 and 9. You must leave them in this sequence. But between them you may insert plus and minus signs, or multiplication signs or dividing signs. You may use the figures in the form (3 + 4 + 5) or (3 times 4) or even in the form 23 or 56. All that is needed is that they remain in their natural sequence. No fractions permitted (like 234/56), nor figures of the type of 3^{1}.

The result must be 100.

I'll add that it can be done in several ways.

Is This Your Real Name?

THINKING about a concluding item for this column, the fact that the last two words always are my name reminded me of the most surprising question I ever got after a lecture. It was in Chicago and the custom of the particular group which sponsored my lecture was to admit written questions only, "to avoid speeches from the floor." One of these written questions read: "Is this your real name?"

I first asked back to find out whether the question concerned my own name and I heard a timid "yes," followed by the question whether it should not be Wilhelm or William. Since others may have worried about the same important problem, I'll give an answer here (as I did in the lecture hall) hoping that this will end the discussion.

No, my first name is *not* Wilhelm or William, it *is* Willy, as stated on the certificate of birth, the certificate of baptism, the certificate of confirmation and my old (German) passport. Willy (in this spelling and this spelling only) is a separate, full-fledged and officially recognized name. Contemporaries who have the

same name are Willy Brandt, the mayor of West Berlin, and Prof. Willy Messerschmitt, the airplane designer. Actually I was named after Prof. Willy Stöwer, a painter who around the time of my birth had the pleasure of knowing that reproductions of his paintings could be found in any German home. They were of ships, usually the High Seas Fleet.

As for my last name, it means "cliff" or "rock" (*e.g.*, Loreley, the first part of that designation being spelled "lure" in English). I probably had an unfortunate ancestor who was the unproud owner of land full of big rocks. I recently came across an English name with the same meaning: Stoneacre. But for those who are likely to check with books on the origin of names, I wish to add that I have done so myself. Both works I checked — one about fifty years older than the other — agree: *Ley*, "rock" or "cliff," or else derived from St. Eligius.

I didn't think the St. Eligius part could possibly apply to me, but just on principle I checked on St. Eligius and learned that he is the patron saint of the blacksmiths. Now I'm not sure which is which. My father's father was a blacksmith (until he opened a tavern) and he told me that his smithy had been family property for generations. In fact, he believed that his ancestors had settled in East Prussia as armorers to the Teutonic Knights.

In that case, I won't have to pity the unknown ancestor who was stuck with rocky land but can sign off in the knowledge that my name is really Smith.

—WILLY LEY