ENORMOUS WEIGHT OF THE WORLD

By George Gray Haven

Any one who says he has the weight of the world on his shoulders would better stop and think a moment what that means. Modern science, always busy with its scales, weights and measures, has put the earth in its balance, and has determined its weight in such fashion that even the ancients must have doubted the myth of poor old Atlas supporting the world, had they known the truth as we know it, to twenty-eight places of decimals.

Few schoolboys who have studied Newton's laws of gravitation have been very much thrilled by them. In fact, they have found it difficult to remember the laws the day after, to say nothing of the day of examination. Recently, however, a young instructor, Rhinehard A. Wetzel, in the College of the City of New York, conceived the brilliant idea of getting his students really interested in gravitation by actually weighing the earth.

He explained his plan to his class. They were interested. Then he told them that, although it had been done abroad several times, as far as he knew it had never been attempted in the United States. They became enthusiastic.

"Get it in grams," exclaimed one of the more ambitious students with bated breath, with a vision of obtaining a number carried out to unthinkable length.

So in grams Mr. Wetzel got it.

It proved to be a very fascinating thing, too; so much so that thousands of visitors to the college flocked to the physics research laboratory, and the apparatus has been placed on public exhibition, so that every one may take a peep at the machinery for weighing the earth.

The apparatus is extremely delicate, though comparatively simple; in fact, one would think it was designed for weighing an atom rather than a planet. It is known as a "gravitational balance."

It consists primarily of a very thin wire, only 3.5 centimeters long, bearing at each end a little silver ball weighing exactly one gram. This wire is suspended horizontally from a very fine quartz fibre attached to its centre, thirty centimeters in length, so fine as to be almost invisible to the eye. In fact, it is finer than the finest thread spun by a spider, yet as tough as though it were a filament of steel. It is very elastic.

The whole thing is encased in an airtight little glass box about three inches long and less than an inch deep, the quartz fibre hanging down through a brass tube set on this box. Not even the slightest air current can affect it.

Then this much of the apparatus is placed on a vibrationless pier of concrete which runs down into the earth through the floor of the laboratory so as to be absolutely free from the vibration of the building. Even then the passing of a wagon on a near-by street affects it slightly. Therefore the actual observations of Mr. Wetzel had to be carried on stealthily in the dead of night between the time when the last joy-riders had rolled homeward and the first milkman went his rounds.

The rest of the apparatus consists of two large balls of lead, uniform in density, very carefully cast in Germany, where all the essential parts of the apparatus were made to order. In fact, in cash, it cost just about one hundred dollars to weigh the earth, though the labor and care involved would increase that outlay considerably if they could be reduced to dollars and cents. They are not estimated.

These balls of lead are placed on a wooden table built around the pier, but not touching it at any point, and they are arranged so that they can be moved back and forth on horizontal bars. The centres of the big lead balls and little silver balls are exactly in the same plane.

Now, Newton's law is that masses attract each other directly in proportion to their mass and inversely in proportion to the square of the distance between them. The problem was first to find out how great was the attraction of the lead balls for the silver balls. This was done by placing the two lead balls in a certain position and noting the position of the silver balls suspended by the quartz fibre.

"When the lead balls stand as they are," said Mr. Wetzel, "the silver balls remain stationary, the opposite attractions counter-balancing each other. Now I begin to push one lead ball in one direction and pull the other lead ball in the other direction, and that little dumbbell in these begins to twist on its thread of quartz, each silver ball getting a little bit closer to the lead ball nearest to it. When we have pulled the silver balls thus as close to the lead balls as possible, the degree of the twist of the quartz thread will be the measure of the attraction exerted upon the silver balls. But how can we measure the twist of a thread which we can hardly see?"

This is done by means of a very little mirror fixed on the quartz fibre. A beam of light is shot in on this mirror, and is reflected back by it on a long, graduated scale placed several feet away. Its position on the scale is noted. Then the leaden balls are moved.

The silver balls, as we have seen, then move through a very minute arc, the quartz fibre is twisted ever so little, the mirror reflects the beam of light at an almost imperceptibly different angle, and the difference, magnified by the distance at which the graduated scale is placed, is read by Mr. Wetzel by carefully noting the new position on which falls the beam of reflected light. The angle turns out to be about 1.7 degrees. This method is the same as that used in the finest galvanometer in measuring electric currents also.

Over and over again this process was repeated, night after night, until at last, after many observations, an average was struck of them all, on the theory that it would be more nearly accurate than any single observation.

The purpose of all this was to determine what is known as the "constant of gravitation," denominated "G." This was the first section of the experiment. The second was to apply the result to the earth.

The application involves some mathematical operations so formidable that they may well be touched lightly. It is all in the famous C. G. S. system—the "centimeter-gram-second system," which you perhaps recall from your sophomore mechanics. In these equations M prime represents the weight of the world, and the mathematician reduces it to 6,030,000,000,000,000,000,000,000,000 grams.

So the mass of the earth is determined—mass rather than weight, for weight really is the attraction of the earth for another mass, and it can hardly be properly said that the earth has "weight"—that is, attraction for itself. Expressed in words, this result may possibly be read as six billions and thirty millions of billions of billions of grams.

It is already known how the masses of the sun and various planets compare proportionately with the earth; and on a chart Mr. Wetzel placed the result in grams, worked out on the basis of his weighing of the earth. The figures are staggering.

Mr. Wetzel is now engaged in other interesting and minute studies in physics, such as an investigation by which he expects to show that the attraction of gravitation varies slightly with different substances, and is not absolute. This had already ben hinted at by Professor Simon Newcomb before his death. Another investigation has to do with the possible discovery of a "gravitational insulator"—something that will reduce the attraction due to gravity. Still another is the attempt to weigh the exact impact of a sunbeam.

This method of weighing the earth is not new, although the result is different from that obtained before, and is the first result on record, as far as I can find, worked out in this country. Presumably, also, it is more accurate, since the City College apparatus is more delicate than any hitherto used, and has eliminated or reduced several previous sources of error.

In fact, the principle employed, which is that of the torsion balance, was first devised by an English physicist, the Rev. John Michell, at Cambridge in 1780, though he did not live to apply it himself. He was the real inventor of the torsion balance, which was later "reinvented" and applied to measuring electric currents by Couloumb, who has received the credit for it. Michell's apparatus was passed to Dr. Wollaston and then, in 1798, passed to Henry Cavendish, the eccentric scientist who is famous, among other things, for the discovery of the composition of water out of oxygen and hydrogen. Cavendish and Michell had been elected to the Royal Society the same year, and to Cavendish belongs the honor of having first applied Michell's method.

The result has been that the method has been closely associated with his own name. He sought to find out how much denser the earth was than an equal volume of pure water, a method which yields the result in a slightly different way from that of Mr. Wetzel. His apparatus consisted of two lead balls, two inches in diameter, at opposite ends of a rod six feet long, suspended by a forty-inch wire. Two other larger lead balls, of twelve inches diameter, weighing three hundred and fifty pounds, were used in much the same way as in the City College experiment. The whole thing was roughly enclosed in a great case to protect it from air currents.

The result arrived at by Cavendish was that the earth was 5.45—which was raised by later experiments to 5.67—times as dense as an equal globe of pure water. Any one who wants to carry it out can do so. There are 259,800,000,000 miles in the earth, and each mile contains 147,200,000,000 cubic feet. Each cubic foot of earth averages 5.67 times the weight of a cubic foot of water, and the weight of a cubic foot of water is about 62.5 pounds. There's an evening's fun if one wants to figure it out. Cavendish's result was three-tenths of a per cent smaller than Mr. Wetzel's.

Several others have repeated Cavendish's experiment, among them being Professor Boys, of Oxford, twelve or fifteen years ago, who invented the quartz or silica fibre, which is really a grain of sand spun out into incredible length. Boys did not rest his apparatus on a concrete pier as Mr. Wetzel did, and often he had to wait three days for his balance to come to rest. Wetzel had to wait only seven minutes for the balance to come to rest.

Boys arrived at a result of 5.527 for the density of the earth. His apparatus was so delicate that once he was interrupted by an earthquake, thousands of miles away, which was detected by him only because he happened to be weighing the earth at the time. The smaller the apparatus, the better the result, it has been found, within certain limits. Boys had an apparatus less than a centimeter in size, almost microscopic. It was too small, just as that of Cavendish was too large and unwieldy. That of Mr. Wetzel was designed to strike the happy medium.

The French professor, Alfred Cornu, the Bohemian, Braun, and others have used the torsion balance in weighing the earth. Bailly, a London stock broker, in the middle of the last century made over two thousand observations, using apparatus similar to that of Cavindish, in his own private laboratory. He arrived at a value of 5.66 for the density of the earth. Another observer, Harkness, made it 5.576, while Wilsing at Potsdam made it 5.59.

There are at least three other ways of weighing the earth. The first man who ever tried it was Bouguer, in 1740. He had noted that a plumb-line deviated from the vertical when suspended near a mountain, and he tried three experiments, one at sea level, one ten thousand feet high, on the plateau near Quito, Equador, and another sixteen thousand feet high, on Pichincha. Another experiment was made at twenty thousand feet (above the snow line), on Chimborazo. His experiments were very faulty, but he did succeed in showing that the earth as a whole was much denser than the mountains on it.

Then the British Royal Astronomer of that day, Maskeleyne, sought to repeat the experiment on the mountain Schiehallion, in Perthshire, Scotland, and in 1774-1776 it was done. The deviation of the plumb-line was measured and was found to be six minutes. Then after careful surveys the density of the mountain was computed and, by the mathematical work of Mr. Hutton, the result was secured that the earth was 4.5 times as dense as water. Subsequent recalculation of the density of the mountain gave the result 4.71.

Among others who have tried it was an American, Thomas C. Fendenhall, once professor of physics in the Imperial University of Tokyo, and later president of Worcester Polytechnic Institute. He worked on Fujiyama, the sacred mountain of Japan. Another American, in Hawaii, Erasmus Darwin Preston, tried the method on Haleakala, an isolated volcano on the island of Mauri, and also on Mauna Kea. The results are given in a table compiled by Mr. Preston, the result for Haleakala seeming to Preston to be the better.

The trouble with this method is that one must have an isolated mountain, else the surrounding mountains will neutralize the pull of the mountain being studied. Also, borings must be made in the mountain to determine its character and, at best, the average density is pretty nearly impossible to determine with anything like accuracy. On the other hand, a lead ball, such as used in the torsion balance experiments, has a naccurate and uniform density.

Another method was that first tried many years ago by Airy, at Harton, England, in a colliery near Newcastle. Airy used an invariable pendulum. The principle was that the difference in oscillation time of the pendulum at the surface of the earth, and one thousand two hundred and sixty feet below at the bottom of the mine, could be used to calculate the density of the layer of the earth between the two points.

It was recently proposed by the United States Geological Survey to use the pendulum method on the apex of the great Pyramid, and then in one of the chambers at the base. Thus, by calculating the density of the pyramid, the weight of the earth could be arrived at. Airy's method is not accepted as against that of Cavendish, and it is believed that he himself was not entirely satisfied with the results, and planned to repeat the experiment before he died. It has more recently been used by Von Sterneck.

But of late years, in 1891, Professor John Henry Poynting, of Birmingham, has developed still another method which may be described as almost precisely "weighing" the earth. Poynting used actual scales and weights of very great delicacy.

Two fifty-pound weights of lead were balanced on opposite ends of a rod. Then a three-hundred-and-fiftypound weight of lead was moved under one of them, just one foot below. The effect was measured.

Of course, the increase in the pull downward on the one suspended ball of lead was very minute and it had to be carefully noted to be discovered at all. Poynting performed the experiment in a cellar, and observed the effect by means of a telescope through the floor of a room above. No one could walk in the house while he was at work. Even the moving of the three-hundred-and-fifty-pound weight had to be subject to correction, for it tilted the cellar floor in the proportion of one inch in ten miles. Poynting found that the fifty-pound weight was increased by one two-hundred-and-fiftieths of a grain.

As Poynting put it, if all the 40,000,000 people of Great Britain were placed in one scale-pan, would one small boy or so make much difference? That was the difficult measurement he had to make—a difference of one in 90,000,000. His result was that the earth weighed 12,500,000,000,000,000,000,000,000 pounds. Mr. Wetzel's weight reduced to pounds would be 13,266,000,000,000,000,000,000,000, pounds — a mere trifling difference of 766,000,000,000,000,000,000,000 pounds. In tons, the weight found by Mr. Wetzel is seven thousand billions of billions of tons.

Thus there have been many scientists the world over trying to weigh the earth, and their results have been as various as their methods. It all comes back to the calculation of the relative density of the earth compared with an equal globe of water. Some get it as low as 4.5, others as high as 6.6, while the probable truth is somewhere between. Before any of them started to calculate it by actual experiment, the immortal Newton, having laid down his laws, gave it as his shrewd guess that the density would be found somewhere between five and six times that of the density of water. Newton's guess is as good as modern observation.

His First Valentine

Johnny Brown, oh, Johnny Brown,
Sadie Jones' beau!
Giving her a Valentine—
We saw you, too, and so
There isn't any use in your
Denying it, you know!

Youthful love, oh, youthful love!
What does Johnny care?
For days he's saved his pennies up,
All his all is there—
In Sadie Jones' valentine,
Which praises Sadie's hair.

Youthful love, oh, youthful love!
What makes Sadie shy?
Why does she turn from Johnny Brown
With bashful, downcast eye—
Then reach her little hand behind
For Johnny's rhapsody?

That presbyter, Saint Valentine,
Has said, on this his day,
No lover shall unto his lass
His love in vain display—
No matter be she Sadie Jones
Or Lady Robelay!

So, send the little tokens round
And choose, each lad, his love;
(The little, tender tokens
With the Cupid and the Dove),
That jolly, old saint, Valentine,
Is watching from above!

—C. L. ARMSTRONG.

THE THERMOMETER'S GROWTH

There are several claimants for the honor of inventing the thermometer, among them being Robert Floor, Cornelis van Drebbel, and Santorio. The former has the advantage over the two latter, it seems, though the instrument invented by Galileo in or about the year 1579, is undoubtedly the forerunner of all the others.

The early instruments were air thermoscopes and could not be relied upon because they varied with the air pressure, though the ultimate test of all thermometers today is the air thermometer. Galileo was the one to introduce the alcohol instrument, probably in 1611, though the date is not definitely known, and this was a great stride ahead, leading as it did to the linseed oil device of Sir Isaac Newton, and that in turn to the mercury thermometer of the present day.

The scale has always been a source of difficulty, and a satisfactory way of determining what it should be is something that many scientists have labored for, with widely different results. The absolute zero of temperature would be a natural beginning, but this is impracticable.

Zero is a word which comes to us from the Arabic through the Spanish and its meaning is literally "empty." Its actual meaning would therefore be utter absence of heat. This is something that cannot be obtained, hence the various points at which zero has been located. Fahrenheit's discovery of the fixed point at which water boils and the point at which ice melts—or water freezes—led to the scale as we now have it.

According to Sir Samuel Wilkes, Fahrenheit's thermometer was constructed from one made many years before by Sir Isaac Newton. In 1701, Newton proposed anonymously a scale which he used on his linseed oil thermometer. He was at this time secretary to the Royal Society and the paper written by him in regard to this instrument is now in the transactions of the society for that year.

The scale which we now use is Fahrenheit's elaboration of this scale of Newton's. The decimal system was not in use at that time and Newton proposed to make the temperature of freezing water zero, and that of the blood of a healthy man twelve degrees. Some time after this, for the sake of convenience, the degrees were divided into two, thus making the body heat twenty-four degrees above zero and the boiling point fifty-three degrees. Years after when Fahrenheit made his mercury instrument he divided them again, this time into fourths. That gave the boiling point two hundred and twelve degrees and the body ninety-six degrees. When he found that he could get a lower temperature than freezing he moved zero down to that point, which brought the number eight of Newton's to thirty-two degrees of Fehrenheit. That is the way it now stands.

Gabriel Daniel Fahrenheit was born at Dantzic, Prussia, on May 14, 1686 From his boyhood he was a close observer of nature, and when only twenty-three years of age, in the remarkably cold winter of 1709, he experimented with snow and sal-ammonias, or common salt, and found that he had produced a degree of cold equal to the coldest day of that year.

As that day was the coldest that the oldest inhabitant remembered, he immediately concluded that he had discovered the lowest degree of temperature known to the world, either natural or scientific. His original scale covered one hundred and eighty degrees, with zero midway. Above, it went to ninety degrees, or temperate, and below it registered minus ninety, which was the temperature of the mixture of ice and salt, believed by him to be the greatest possible cold.

The final change in Fahrenheit's scale already described was made in 1714, five years after his famous experiment.

In 1730 Reaumur made alcohol thermometers with their zero at the freezing point of water, but they were unreliable and unequal in their indications. Deluc introduced a mercury thermometer which, with Reaumur's name attached, is still popularly used in Germany, Holland, and other parts of Europe.

The first centesimal scale was that of Celsius, adopted in 1742, but it is to the great Linnaeus that we are indebted for the rational mode of reckoning known as the centigrade. This places zero in melting ice and one hundred degrees in boiling water, and it is used universally in laboratories and for every scientific purpose in all except English-speaking countries. It will, no doubt, ultimately become the system in use everywhere and for all purposes. The argument in its favor is that it starts from an absolute and universal point, which we now know as thirty-two degrees.

The Fahrenheit scale is convenient for some work on account of the shortness of its degrees, which makes great accuracy in recording possible, but the other is far more convenient under all conditions, and its use is so general now that it seems to be only a question of time when it will entirely supersede the older reckoning.

GUESS WHO THIS IS

An unwitting caricature of a well-known British Columbian, by an artist who never saw him. It was published in Throne & Country, an English periodical, and was intended as a caricature of an actor.

PHYSICIANS VS. SPECIALISTS

"We are living in an unfortunate age, so far as the work of the physician is concerned. Not only the profession but the people want quick action. Few are willing to wait for results of medicine, which is the only means of restoring a perverted function. We have become so crazed by the wonderful and spectacular work of the surgeon that the desire prevails to have everything cut out. The family physician has lost his job. Every one runs to the specialist, who often sees many cases through a biased pair of spectacles. With all his expert knowledge the so-called specialist very frequently specializes with too many diseases, and his treatment is liable to become prejudicial if not empirical. The family physician—if such a man exists—is the one who should treat these cases, for the successful result requires time and careful individualization in each instance."—Dr. H. V. Halbert, Chicago, in The Clinique.

"Can you tell me, my boy," said the prim teacher, "why the race is not always to the swift?"

"Yes'm," said the little boy, promptly. "It's because sometimes their tires bust."—Baltimore American.