A REASONING HORSE.

Hardly a day passes but the newspapers have something to say of the wonderful mental performances of "clever Hans," "*der kluge Hans*," as Herr Von Osten's stallion is called. Indeed, some wordy controversies have been waged over him. Some hold that he actually reasons; others skeptically assert that his intelligence is simply the result of ingeniously concealed trickery on the part of his trainers. An investigation conducted by scientists, however, would seem to indicate that the horse is really what his owner claims him to be, an intelligent four-footed animal, capable of making simple arithmetical calculations, and even of ratiocination. Dr. Heinroth, of the Berlin Zoological Garden, has this to say of Hans' wonderful feats in a recent number of the Illustrirte Zeitung:

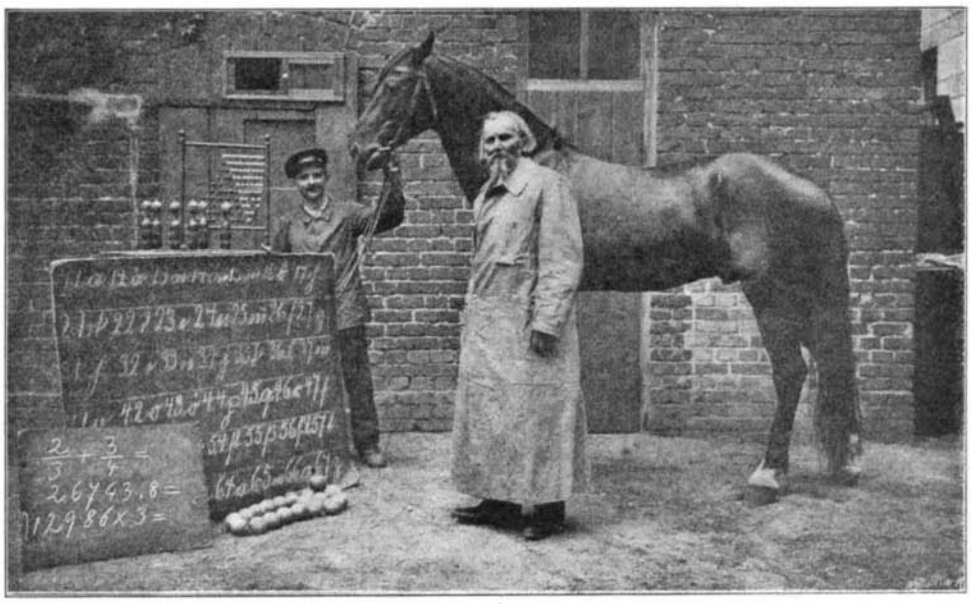
"For many years Herr Von Osten, who was at one time a tutor of mathematics, has made it his task to determine the intellectual possibilities of a horse. His first stallion, with whom he succeeded in doing remarkable things, died at the end of eight years. Hans, his second acquisition, has been under his care for four years. Von Osten has no desire to sell the horse or to display him for money in public. He is instructing him in the interest of science alone.

"In my presence Von Osten asked the horse to add such sums as 6 + 2 and 4 + 3. The horse indicated the correct answers by stamping with his right fore-hoof. It is to be remarked that during the calculations Von Osten feeds Hans with carrots. Von Osten declares that without the carrots the horse would refuse to work. Hans has never felt the touch of a whip. This, after all, is not very strange; for, as Von Osten puts it, carrots are to Hans simply what honors, titles, rank, and money are to men.

"I asked 'What are the multiples of 12?' The answer came almost immediately. Sums such as 72 + 14 are correctly given. The actual words (in German) 'What is the difference between 43 and 6?' were read, and the answer immediately pawed. No numerals appeared on the blackboard. Surely, this is more than the trickery of training. It should here be mentioned that questions can be put by any bystander. Hans is able to convert common fractions into decimal fractions. He can also tell time by the clock. If he is asked, 'It is now 40 minutes after 12; how many minutes will elapse before one o'clock?' he immediately answers with twenty strokes of his hoof. These are simply a few among a great number of questions that were put.

"Hans knows the coin of the realm and the value of playing cards. King, queen, ace, and the like are differentiated by the hoof. He picked out a badly-worn German 50-pfennig piece from several coins. From a number of pieces of colored cloth laid upon the ground he will select any color he is ordered to choose. 'Is it green?' you ask. Five strokes of the hoof is the reply; and the fifth cloth proves to be green. The colors may be changed in any manner; still the horse will pick out the correct one."

Dr. Heinroth concludes his article by stating that he is quite convinced of the impossibility of any deception. He has questioned the horse in his stall in the absence of its owner, and he has received answers as clear cut and as precise as those given in the presence of Von Osten.



The Reasoning Horse "Hans" and His Owner.

"Hans" Answering an Arithmetical Question by Pawing With His Hoof.

A REASONING HORSE.

Some figures have been published on the production and commerce of quinine. According to the report of the chief of the government plantations in British India, the Madras government produced 15,711 pounds of quinine in 1902, and the Bengal government 11,927, making a total of 27,638 for India. Java produced and exported 43,750 pounds. As to the exportation of bark for 1902, Java heads the list with 14,726,000 pounds, followed by India with 2,020,000, Ceylon with 407,000, South America 775,000, and Africa 180,000, making a total of 18,108,000 pounds. This represents the bark which has been supplied to the trade, and it is estimated to contain 861,810 pounds of quinine. Adding these figures to the above-mentioned quantity produced in India and Java, we have a total of 933,200 pounds, which represents the total amount of quinine produced in 1902. As to the quinine-producing establishments, there are 5 in France, 3 in England, 2 each in Germany and Italy, one each in Holland, Java, Bengal, and Madras, besides those in America. The two leading markets are Amsterdam and London, but the latter has become less important since the development of the Java production.

WHEN WAS THE PHOTOGRAPH TAKEN?

BY PROF. WILLIAM F. RIGGE.

I wonder what the reader will say when I show him this photograph of the Creighton University Observatory [at Omaha, Neb.] and ask him to tell me when the photograph was taken. I will allow him every liberty but one—he must not ask the photographer.

The condition is rather severe, but not worse than my own, because I do not know the photographer, nor could I after diligent inquiry find anyone who knew anything at all about the picture.

I am very fond of mathematics. It seems to run in my blood. I looked upon this picture for years, and was convinced that the shadows in it had automatically and unmistakably stamped the date and time of its taking upon the photograph. I investigated, I measured, I computed. And now I know when the photograph was taken. If the reader is willing, I will take him into my confidence, and show him how the problem was solved. I will investigate three things: 1, whether it is possible in principle to obtain the date of a photograph from the shadows in it; 2, whether it is possible in practice; and 3, how closely our results are to be trusted.

The direction in which the shadow of an object is cast evidently depends upon the sun's position in the sky, and ought therefore to serve as a means to obtain this position. Now, the twofold motion of the sun is causing it continually to change its position: the diurnal motion is carrying it about in a circle whose center is at the celestial pole, the annual one is carrying it toward or away from the celestial equator. As these two motions are independent of one another, every determination of the sun's position by means of a shadow it casts ought to give us its place in both of these orbits, that is, give us the time of the day and the day of the year. Fig. 2 will show us how this is done.

Let us imagine the heavy line AB to be the shadow cast upon a horizontal surface by the vertical rod OB. With the radius AO let us describe a miniature celestial sphere about the point A as a center. Let $NESW$ be the great circle of the horizon with its cardinal points, and $NPZS$ that of the meridian. Z, vertically over A, will be the zenith, O will be the sun's position, and P, so taken that the angle NAP is equal to the latitude of the place, will be the celestial pole. The points Z, P, O—zenith, pole, sun—are the vertices of the great astronomical triangle with which we must become acquainted. The side PZ is the complement of the arc NP, which is equal to the latitude of the place. The side PO is the sun's polar distance, and is the complement of its declination, or of its distance from the celestial equator. The side ZO is the sun's zenith distance and the complement of its altitude OH or of the angle OAH. The angle at the pole, ZPO, is called the sun's hour angle, and is proportionate to the time elapsed since the sun crossed the meridian. The angle at Z, PZO, or its equal NAH, is the sun's azimuth, or bearing, as a surveyor would call it, reckoned from the north point of the horizon. The angle at O, POZ, is called the parallactic angle. We have no need of it in our discussion. In this triangle the hour angle ZPO determines the sun's position in its diurnal orbit and gives us the time of day; the side PO, the complement of the sun's declination, determines the sun's position in its annual orbit and gives us the day of the year. The measurement of the shadow AB of the rod OB must, therefore, in some way give us the angle ZPO and the side PO. It does so indirectly. Spherical trigonometry teaches us that if any three of the six parts (three sides and three an-

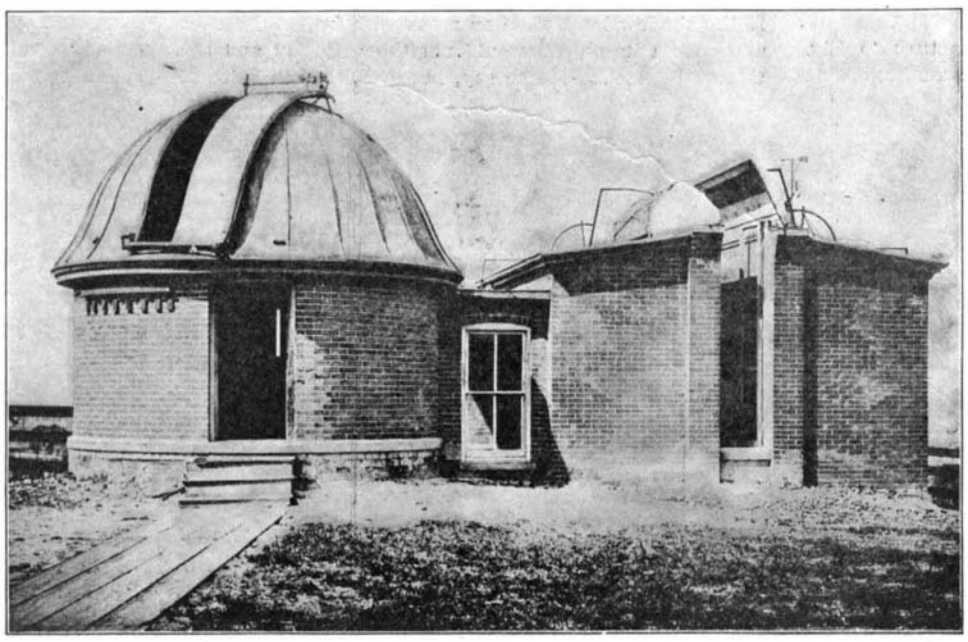


Fig. 1.—WHEN WAS THIS PICTURE TAKEN?

gles) of a triangle are given, the other three are thereby implicitly and definitely determined and can be found by computation. Now we have three such parts given in the triangle *PZO*. The first is the side *PZ*, the complement of the latitude of the place where the shadow is cast. The second is the angle *PZO*, the sun's north azimuth, the supplement of its south azimuth *OZS* or *HAS* or *BAD*. This latter angle *BAD* is determined in the right plane triangle *BAD* by the sides *BD* and *AD* (or *CB*), the distances which the shadow falls east [or west] and north [or south]. And finally the third part is the side *ZO*, the complement of *OH*, or of the angle *OAH* or *OAB* the sun's altitude, this latter angle being found in the right plane triangle *OAB* by the sides *OB* and *AB*. Hence a measurement of the position of a shadow with respect to the object that casts it, that is, of the distances *BD*, east or west, *BC*, north or south, and *BO*, downward, or of its three space co-ordinates, as a mathematician would name them, will furnish us with all the data necessary and will determine the day of the year no less than the time of the day when the shadow occupied that particular position. It is evident that the object casting the shadow need not be a vertical rod, nor that the shadow should fall upon a horizontal plane. All we need absolutely is the direction in space of the line joining the shadow and the object, that is, technically, its altitude and azimuth, these data being best determined in practice by means of the three space co-ordinates, measured by a plumbline, level, compass, tape line, or similar instruments.

We come now to the second and practical part of the problem, the actual measurement of the three co-ordinates, *BD*, *BC*, and *BO*. And here we are at once confronted by two difficulties. The first and greatest of these lies in the identification, or rather in the determination of the exact location of the shadow of a known point upon a photograph. In our reproduction of the photograph of the Creighton Observatory it will be seen that the stone coping on the west side of the meridian slit in the transit room casts its shadow very conspicuously on the window casing. The shadow falls exactly upon the middle of the flat western side of the casing and on a level with the mortar line between the tenth and eleventh bricks below the coping stone. This casing is in reality two and a half inches wide, but upon the original photograph it is only 12 thousandths of an inch. An error of one thousandth of an inch in the localization of the shadow upon the photograph would make the result uncertain by a day. The second difficulty is a minor one, and lies in the practical measurement of the three co-ordinates. This measurement is, of course, executed upon the object itself from the information obtained from the photograph. It was found that the shadow fell 31.35 inches downward, 27.70 inches eastward, and 12.25 inches northward. These data coupled with the latitude of the place, 41 deg. 16 min. 6 sec., tell us by computation that the sun's declination was 15 deg. 15 min. north and the hour angle 41 deg. 12 min. or 2 hours 45 minutes afternoon, local apparent solar time. Reference to any large and good celestial or terrestrial globe, to the Nautical Almanac, or to similar sources, shows that the sun has the declination +15 deg. 15 min. on May 2 and August 11, that is on two dates, at one of which the sun is going north and at the other going south. In order to determine which of these two dates is the correct one, we must resort to evidence other than that furnished by shadows. In our case we see upon a close examination of the original photograph, that the condition of the grass in the foreground and of the trees in the background is such as to point unmistakably to the earlier date, that is, to May 2. Now, as the sun is 3 minutes fast on May 2, and as Omaha clocks are set 24 minutes fast in order to show central time, this gives us May 2, 3.06 P. M., central standard time, as the date and time when the photograph was taken.

In order to confirm our result, let us turn to Fig. 3, which represents a part of the window casing drawn to actual size, two and a half inches wide. The line *AB* is on a level with the mortar line between the tenth and eleventh bricks, and *DE* and *FG* are on a level with the next mortar lines above and below *AB*.

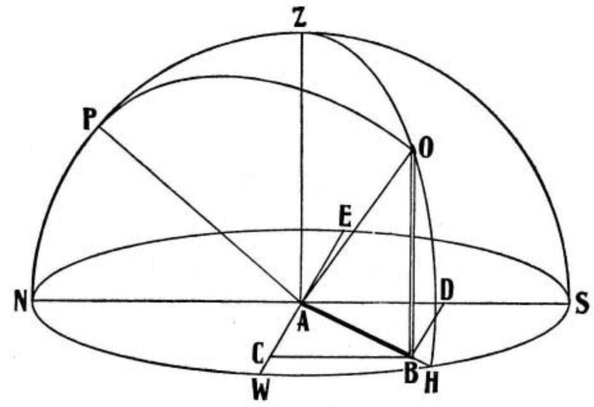


Fig. 2.

C is the location of the shadow, as shown on the photograph. The long oblique line passing through *C* shows the path of the shadow on the casing on May 2 and August 11, and the position of the shadow at intervals of one minute before and after its passage through the critical point *C*. The other two long oblique lines show the path of the shadow five days before and after, and the short lines show it for every day. After making due allowance for the practical difficulties of the problem, is it claiming too much to assert that in this case the date is correct within two or three days, and the time within as many minutes? If the shadow had fallen as many feet as it did inches away from its object, would not the very day and the minute be fixed? I dare say, however, that in spite of

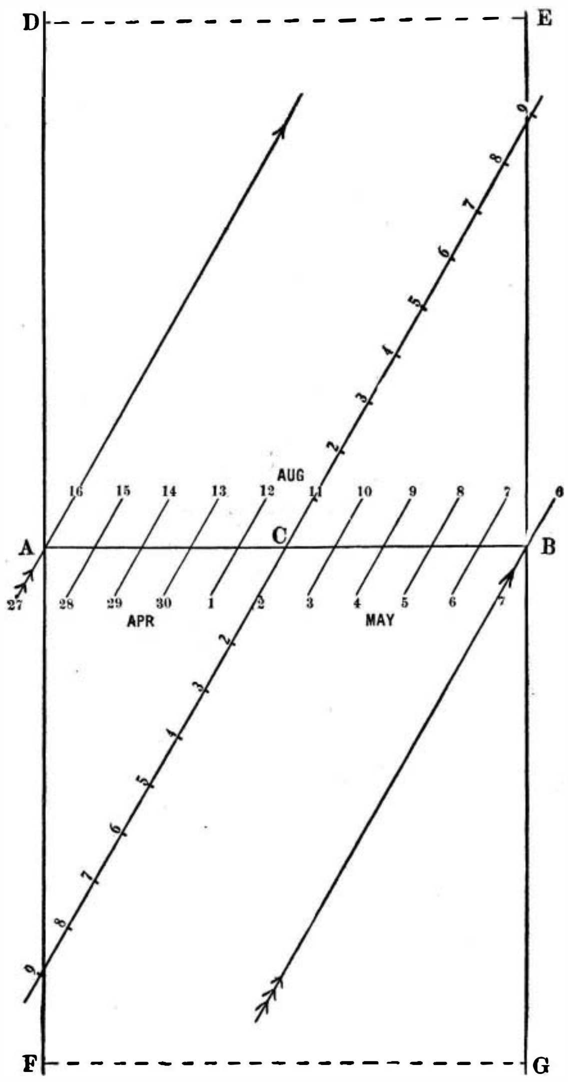


Fig. 3.

all this evidence most of my readers would rely more upon the word of the photographer or upon actual observation than upon all the mathematics in the world. To quiet their apprehensions, let me say that on last May 2 (1904) at 3.06 P. M., central time, the shadow was at the place assigned as accurately as anybody could desire. I will also add that I had finished the computation, and proposed the problem to my students two months before.

"Oh! but you are forgetting a most essential item, the year!" the reader may exclaim.

A half-tone of this photograph of the Observatory appeared in the Creighton University catalogue in June, 1894, hence it must have been taken at the latest in May of that year. As it was evidently taken in the sunlight, perhaps the weather conditions may decide the year. The cumulus clouds in the sky, the northwest wind indicated by the weather vane, and the transparency of the air, which on the original photograph allows trees about three miles away and bluffs about six miles away to be seen with great distinctness, show that there must have been a rain a short time before to clear the atmosphere, the wind must have continued to blow from the northwest for many hours, and the barometer must have been high. Prof. L. A. Welsh, our local weather forecaster, has very kindly examined his records and they, together with those kept at our Observatory, prove beyond the possibility of a doubt that May 2, 1893, is the day we are looking for. Not only do the weather conditions shown on the photograph apply to that date in all their completeness, but they also single it out most emphatically from the preceding and following days of that year. And more than that, they also determine the year, because they cannot be made to apply to May 2 or contiguous days in 1894, 1892, 1891, and 1890, and further back than that I need not go for reasons that would not interest the reader.

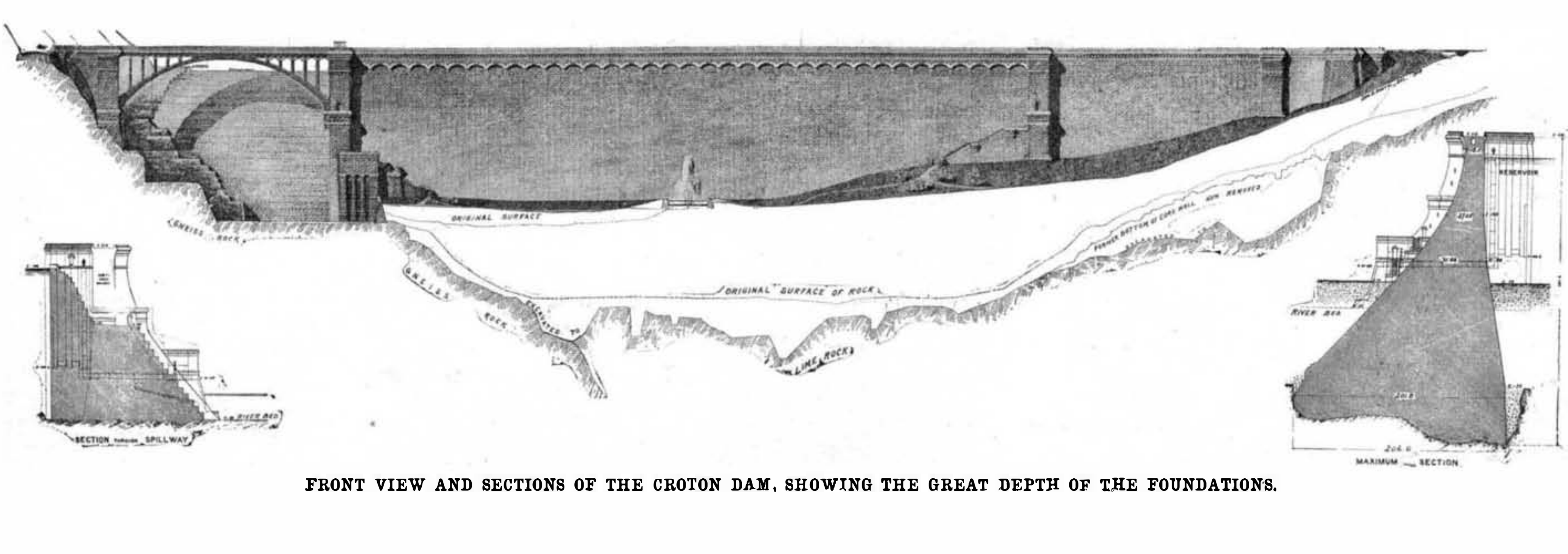
If, therefore, I am asked when this photograph of the Creighton University Observatory was taken, I can answer with an assurance and an accuracy superior to that of the photographer himself if he could now be found and interrogated: Tuesday, May 2, 1893, at 3.06 P. M.

Creighton University Observatory, Omaha, Neb.

COMPLETING THE NEW CROTON DAM.

For the first time in all the many years that it has been under construction, work at the great Croton dam is proceeding with positive energy. The activity is due to a desire to finish the gap in the southern end of the dam, where recent alterations in the plans have seriously delayed the work. In explanation of the delay it will be well to briefly recite the facts.

As originally designed, the Croton dam was to have consisted of a solid masonry structure for about two-thirds of its length and of an earth dam with a center core wall for the remaining third. This core wall was to consist merely of a thin masonry diaphragm impervious to the water, which was intended to seal the earth dam against the passage of any water. The substitution of earth for masonry was made by the then chief engineer, chiefly from considerations of economy. On the accession of the late chief engineer, Mr. Hill, to office, he at once condemned the composite nature of the structure, and recommended that the masonry work should be carried continuously across the valley, providing a homogeneous structure. In support of this recommendation he pointed out that there were strong engineering reasons against the use of the earth and core wall construction, especially in connection with an all-masonry structure. After a board of experts had indorsed his criticisms, the core wall as far as it had been built was taken down, and it was then discovered that the bottom on which it rested was of a treacherous and more or less friable material, which in the presence of water seemed to lose its consistency entirely. Accordingly it was decided to carry down the excavation until absolutely sound rock was reached.


FRONT VIEW AND SECTIONS OF THE CROTON DAM, SHOWING THE GREAT DEPTH OF THE FOUNDATIONS.