or, in a round number as accurate as the data will justify, 240,000,000 miles.

The question now arises as to how many of the stars have angular diameters large enough to be measured. With the present apparatus attached to the 100-inch reflector it may be seen from the above discussion that the lower limit of measurement is 0″.023 for the diameter of a star.

In the January 1921 number of POPULAR ASTRONOMY, page 31, is given a list of probable star diameters determined by theoretical considerations, by Henry Norris Russell, Director of the Princeton Observatory. (See more extended list by Russell in *Publications of the Astronomical Society of the Pacific,* No. 190, December 1920.) In this list only four, α Orionis, α Scorpii, γ Crucis, and α Tauri are above the limit just given. The field of search seems to be very limited, but as the diameter of α Orionis, which heads the list, comes out a half greater than predicted, it may be that some of the others are also within reach of present means of measurement.

To measure a diameter of 0″.01 would require the mirrors m_3 and m_4 in Fig. 4 to be 46 feet apart, and for 0″.001 they must be 460 feet apart. The latter is of course out of the question with the ordinary form of mounting. But, since the telescope need be only large enough to receive the beams of light from the mirrors m_1 and m_2, it might not be impossible to build an interferometer beam 100 feet long, mounted so as to oscillate east and west through an angle of 30° (permitting observation during two hours), and carrying the telescope as a secondary instead of the primary piece of apparatus. This would make possible the measurement of a star of diameter 0″.005, and would greatly extend the scope of the investigation of the diameters, and thus indirectly of the constitution of the stars.

LATITUDE WITHOUT INSTRUMENTS.

By RUSSELL W. PORTER.

"Not within a mile of the truth" usually means that something or other lies very far from the mark. Locating ourselves within a mile of the truth on this immense globe of ours would, however, be considered a pretty close approximation. To do it with only a string, this approximation would seem to be a remarkably close one.

Two winters ago a good friend—William Brooks Cabot of Boston—well known for his exploratory work in Labrador, suggested that latitude could be determined in the field without an instrument of precision. He deplored even the addition of a pocket sextant and horizon to a camper's pack where dead weights must be shaved to a minimum: that the tools irreducible to the explorer—a knife, hatchet and fishline—together with nature's available materials, would suffice to obtain latitude within a mile. He had not put the theory into practice, however.

And the writer, doubting that any such accuracy could be reached, put the method to the test. He was greatly surprised, after several false starts, and hitting luckily at last on a novel expedient, to find that latitude could be obtained with a steel tape to well within a statute mile: time (and hence longitude) correspondingly.

The problem resolves itself into the measurement of a vertical angle. In Todd's "New Astronomy," page 82, is described a simple way of finding one's latitude. It obtains the zenith distance by allowing a beam of sunlight to fall on a graduated arc oriented in the observer's meridian. It will probably give one's latitude to the nearest degree.

If now we take the simple case of the sun on the equator at noon, and suspend a weighted line BC from any convenient support, and from its lower end stretch another line AC to our eye when it sees the sun and the point B in line, we have formed a right angle triangle in which the angle A B C will be our latitude. This statement is made clear in the smaller diagram, where an observer at A finds that the angle between his zenith and the equator (in this case a very distant object lying in the plane of our equator) will always be his latitude.

Now in this triangle A B C the hypothenuse B C is readily and accurately determined. The plumb line may be suspended from the limb of a tree or from a nail driven into the top of a porch post, or on the corner of a house. A good working length is about ten feet. Since the angle we desire is angle A B C, if we can measure the side A C then the sine of this angle is at once found and the angle may be taken directly from a table of sines.

It now remains to work out a convenient means of measuring this sine, and the writer has found that the following procedure gives the most satisfactory results. While a fish line or cord can be used, since the ratio only of A C to B C is required, yet more accuracy is attained with a small pocket steel tape whose feet are divided into tenths and these again into tenths. As these last divisions may be estimated to tenths, we obtain readings to one thousandth of a foot.

The point C at the lower end of our plumb line is next fixed in a secure manner.

I have found it practical to bring the end of a sapling or small log up to the base of the tree when in the wilds, and to drive a nail into the butt opposite to some whole division on the tape. This end of the plumb line is of course already provided for the nail if we use a house corner or porch post.

The other end of the sine line, at A, can be found by the use of a screen or target in which a small hole has been bored, and the target capable of being slid along the tape to any desired position. A sketch of this is shown in the figure. For use with the sun a piece of colored glass must cover the pin hole to protect the eye, but with the stars at night an ordinary visiting card suffices.

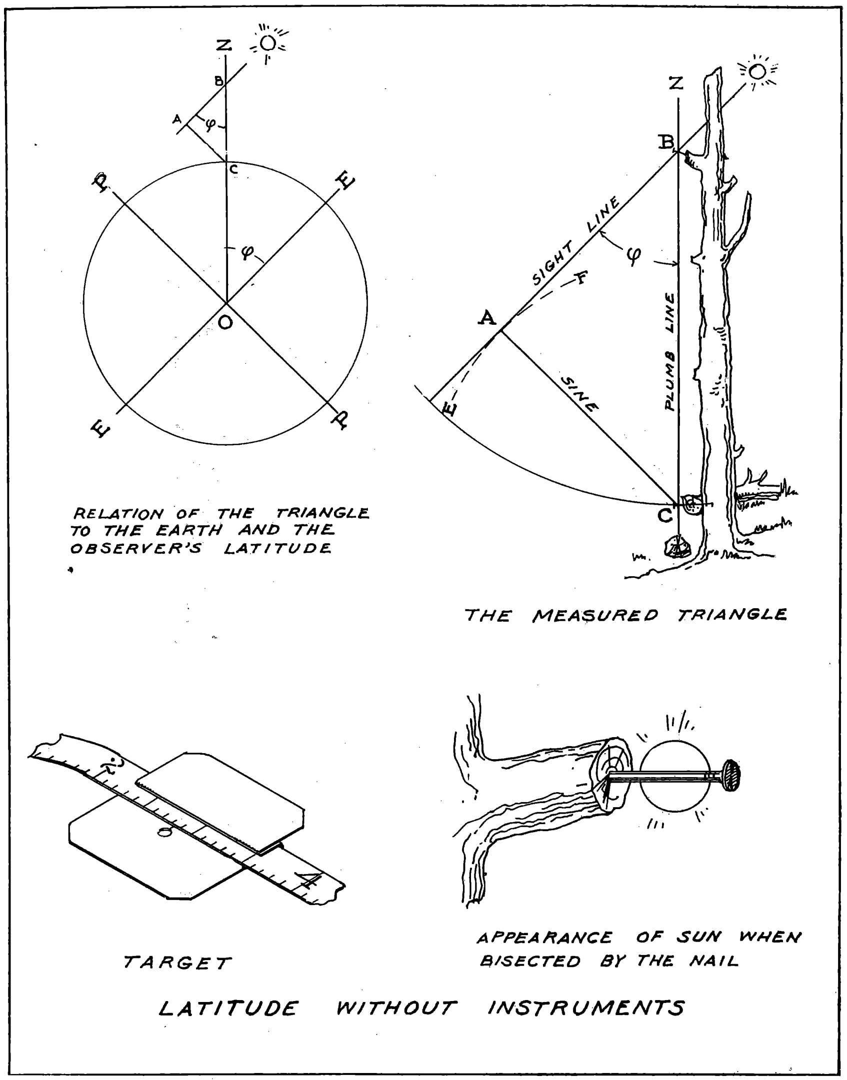

FIG. 1.

If now the buckle of the tape is hooked over the nail at C and the tape drawn taut over the head of the observer as is shown in one of the photographs, a position will be found where the nail at the upper end of the plumb line is seen to just bisect the sun's disc. The appearance then will be shown as in the figure, and the head must be moved up and down and the target shifted until the sun is bisected with the *minimum length of tape*. That is, a position will be found as the target sweeps through the arc E F, where the sun seems to rise towards the nail, remains stationary a moment and then falls away. It is at this middle position that the tape is at approximately right angles to the sight line A B, and the length of the sine may then be read off on the tape just opposite the pin hole.

With a little experience this operation of getting the eye, the target,

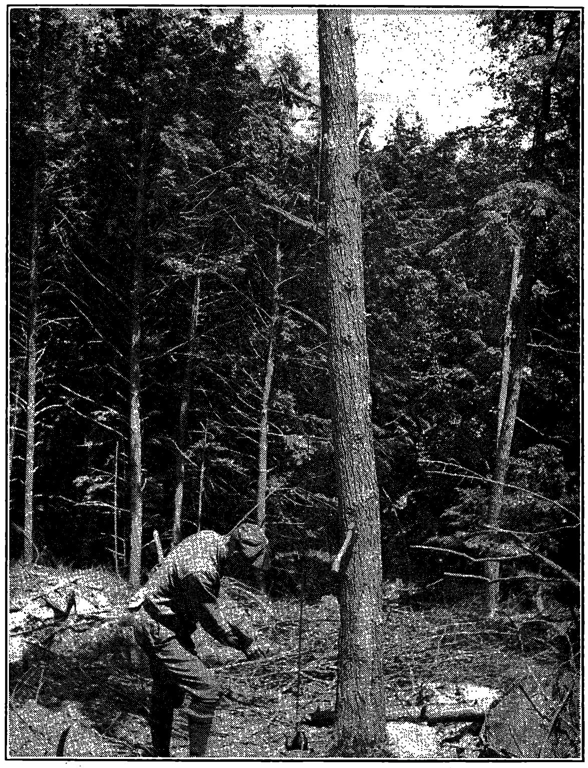

FIG. 2. DETERMINING THE HYPOTENUSE B C OF THE TRIANGLE WITH A PLUMB LINE.

the nail and the sun all in line, becomes an easy one, and if you have been careful in locating these three points of our triangle the observation is finished, and if your plumb line is ten feet, and the sun is on the celestial equator, the angle corresponding to the sine you have measured is your latitude, without further computation.

The sun, however, is on the equator or is "crossing the line" as navigators say, but twice a year—in March and September. Its distance north or south of this position (that shown in the figure) is given for each day in the almanac. It is called the sun's declination. If it is north of the equator—between March and September—this declination must be added to the angle obtained by observation in order to obtain the latitude.

One other small correction is necessary—that caused by refraction. The sun is never really as high as we see it in the sky, because the light coming from it to the eye is bent down on passing through our atmosphere. This correction for the sun in our latitude never amounts to over two minutes of arc: in summer it is less than one minute. By

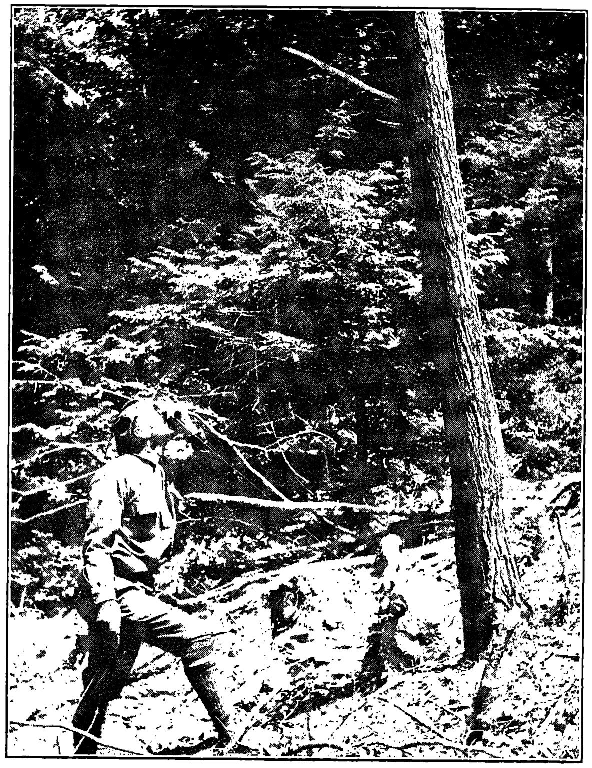

FIG. 3. TAKING THE OBSERVATION. NOTE HOW THE TAPE IS HELD TAUT WITH THE RIGHT HAND.

reference to the figure (1) it will be seen that the angle observed viz. ABC is the same as ZBS: that is, we have measured the angle from a point directly overhead down to the sun—what is known as the zenith distance. This angle, on account of the refraction, is too small, and therefore this correction is always to be added.

That is all there is to it. The steps are as follows:

1st. Fix two points ten feet apart with the plumb.

2nd. Find the angle between this line and a sight line through the upper point to the sun by measuring its sine.

3rd. To this angle add the correction due to refraction, and apply the sun's declination from the almanac—plus if north and minus if south of the equator.

The result is the latitude.

The above description has been written especially for the young

FIG. 4. THE LOWER END OF THE HYPOTENUSE C.

student who would know something of practical astronomy, but who fears it is beyond him; fears that there is something very mysterious about it, involving higher mathematics, years of application and the use of delicate and expensive instruments beyond his reach. The purpose of this article is fulfilled if it stimulates some one to put his knowledge of plane geometry to practical use, and leads him to further inquiry.

To the reconnaissance surveyor, and to the astronomer it may be of interest to know that this method of determining latitude and time is susceptible of considerable refinement. For instance, the triangle may be referred to the centers of the two nails at the ends of the plumb line, and the center of the pin hole of the target. The buckle at the end of the tape may be deformed so that the tape divisions will read from the nail centers. The diameter of the pin hole cannot be much less than 2 mm if stars are used. With the sun somewhat less than a millimeter hole is about right. The bisection of the sun's disc seems to be reliable to less than a minute of arc. An error of one thousandth of a foot in the sine for a summer meridian altitude in our latitude affects the angle sought about half a minute of arc. The following

FIG. 5. THE OBSERVER IS HERE SHOWN WITH THE TARGET SO PLACED ON THE TAPE THAT HE SEES THE SUN BISECTED BY THE NAIL ON THE TREE AT THE UPPER END OF THE PLUMB LINE.

circummeridian zenith distances on the sun, using a theodolite to check the angles are submitted.

LATITUDE FROM CIRCUMMERIDIAN ALTITUDES OF THE SUN AS DETERMINED BY TAPE LINE.

SPRINGFIELD, VERMONT, AUGUST 8, 1920.

Watch 75th Mer. Time			Tape Reading	Zenith Distance		Z. D. Red. to Meridian		Latitude		Res.
h	m	s	mm	°	′	°	′	°	′	′
11	41	30	1457.5	27	17.4	27	12.8	+43	19.8	—1.3
	47	20	1453.0		11.9		11.1		18.1	+0.4
	52	10	1452.5		11.3		11.3		18.3	+0.2
	56	50	1453.0		11.9		10.2		17.2	+1.3
0	2	30	1459.0		19.2		12.0		19.0	—0.5
	8	0	1464.5		25.9		11.4		18.4	+0.1

Length of plumb line, 3179.0mm — mean 43° 18.5

Latitude by theodolite, 43 18.3

The first two columns represent the observations. The third and fourth give the steps in reducing these observations to the meridian. In the fifth column the corrected sun's declination is applied, giving six independent determinations of latitude. The last column shows the amounts by which each determination departs from the mean derived latitude.

Finally in a triangle the size of the one described a considerable departure from the right angle at A may be allowed before it disturbs the angle sought by as much as a minute of arc.

The writer attempted a further improvement by placing a totally reflecting prism at A so that the observer could look down the sine at a convenient angle against a dark background (case of the sun). He found that any improvement in convenience of posture was offset by the vibration and shifting of the objects viewed through the prism due to its unstable mounting. Even the pentagon prism proved of little help.

SATURN.

By ALFRED RORDAME.

Saturn, the most charming of celestial objects and without doubt the most often observed,—its soft golden lustre is eagerly sought by the student in the earliest twilight. The planet which, with its glorious ring system and lovely retinue of satellites, in moderate sized telescopes is captivating, becomes in the larger apertures of superlative grandeur and beauty. The vision, no matter how often beheld, never palls and is the one object that compels an exclamation of admiration by the most indifferent beholder.

I well remember my first observation of Saturn through a home-made telescope, a non-achromatic, constructed with a concave eye-piece. It was merely a repetition of Galileo's view, and had I not previously seen engravings of the planet, would have been as sorely perplexed as the great inventor of the telescope himself. With each improved instrument in turn has Saturn to me proven a source of delight, and in the 16-inch Mellish reflector the planet takes on the aspect of a globe of dull gold, while the ring system shows a variety of tints from pearly white through all the shades of yellow to the dusky blue of the crape ring.

I have lately come across an extract from Huyghen's "Systema Saturnium" which plainly shows the difficulties the early observers had to contend with in explaining the puzzling appearances of Saturn's rings as shown in their inferior telescopes. As is well known, Galileo was the first who discovered anything uncommon connected with Saturn. Through his telescope he thought he saw that planet appear like two smaller globes on each side of a large one, and after viewing the planet in this form for two years, he was surprised to see it be-