HINTS

TO TRAVELLERS.

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EDITED BY A COMMITTEE OF COUNCIL

OF THE

ROYAL GEOGRAPHICAL SOCIETY,

CONSISTING OF

ADMIRAL SIR G. BACK, F.R.S.,

ADMIRAL SIR RICHARD COLLINSON, K.C.B.,

AND

FRANCIS GALTON, ESQ., F.R.S.

FOURTH EDITION,

EDITED BY

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FOURTH EDITION.

Edited by FRANCIS GALTON, Esq., F.R.S. MARCH, 1878.

[The present Edition has been revised throughout; it differs from the preceding one in many particulars, especially in containing a Memoir on Surveys, by Major Wilson, R.E., and a few useful Tables; also the form of the book has been altered for the convenience of Travellers.]

(PREFACE TO THE THIRD EDITION, DECEMBER, 1871. Edited by Admiral Sir GEORGE BACK, F.R.S., Vice-Admiral COLLINSON, C.B., and FRANCIS GALTON, Esq., F.R.S.)

APPLICATIONS are frequently made by travellers to the Royal Geographical Society, for instructions by which they may make their labours useful to Geography.

The Council have always shown themselves disposed to pay considerable attention to such applications, when they proceed from persons who are zealously engaged in preparing themselves for arduous enterprises.

If a specific question be addressed to the Council on some particular instrument or point of equipment, they usually refer it to a Fellow of the Society, whose experience might enable him to afford a satisfactory answer. But a question of a more general nature, on the best instrumental outfit for an inexperienced traveller, is of such frequent occurrence, and demands so lengthened a reply, that the Council thought proper, some years ago, to appoint a Committee* for its full consideration. The Report of that

* This Committee consisted of Admiral FitzRoy and Lieut. Raper, R.N., and contained papers by Admirals Smyth and Beechey, Colonel Sykes, and Francis Galton, Esq.

Committee was printed in vol. xxiv. of the Journal of the Society, and was extensively circulated under the title of 'Hints to Travellers.' When this edition became exhausted, we were requested to take the opportunity of making a thorough revision of the work. This we did, and now that the second edition is out of print, we have again carefully revised the pamphlet. The present [third] edition of the 'Hints to Travellers' will therefore form the answer of the Council, to whomsoever may request information on the subject of which it treats.

The following remarks are to be understood as addressed to a person who, for the first time in his life, proposes to explore a wild country, and who asks, "What astronomical and mapping instruments, and other scientific outfit ought I to take with me? and what are the observations for latitude and longitude, on which I should chiefly rely?" To this end we give a list of instruments, books, and stationery, complete in itself, so that an intending traveller may order his outfit at once. He would then be satisfied that no object of real importance had been omitted, that he had bought nothing superfluous, and that the different items corresponded together in power and in their several uses.

Lists drawn up by different travellers of experience would undoubtedly vary, for there is considerable difference in their practice; but an explorer would never do wrong, who followed to the letter the list we are about to give. His danger lies in adopting scattered hints from many sources, and starting with instruments which, though severally good, are, when considered as a set, incongruous and incomplete; and, secondly, in trusting to the advice of observers who have little experience of the bush.

The outfit we recommend, based on the use of sextants and the mercurial horizon, would suit an explorer in any part of the world, who desired the means of bringing back as good geographical results as the earlier explorers of large tracts of land have ever yet succeeded in obtaining. And in this list, professedly compiled for an inexperienced observer, simple and well-known instruments alone find a place. We are very far indeed from thinking that makers of sextants have yet met all the wants of land travellers, but we *know* that good results may be obtained by such instruments as are to be bought from any good optician. We therefore urge a young explorer to make *these* his mainstay; and if he takes other instruments, to do so more for the purpose of testing and reporting on their performances, than of relying in entire confidence upon them. Again, it is hazardous for a man hastily preparing himself for a journey, to order new apparatus from a maker; he cannot be sure that it will be well made or ready in time, and he may have to set sail in the possession of a strangely-shaped instrument — very delicate, difficult to pack — whose adjustments he has not had opportunity of mastering, and on which it is unlikely he will obtain information after his departure; whilst, if he determines on buying a sextant, and other well-known instruments, he may make his selection out of great numbers that are always to be found on sale, and practise himself in their use, under the tuition of the officers of the ship, during the whole of his voyage from England. It is therefore our object to give a list of instruments with which we advise a traveller of little experience to provide himself, and which will be found thoroughly adequate to do his work.

It should be borne in mind that travellers can seldom attain accuracy in their observations, perhaps hurriedly made, during a first exploration. Latitude within ½ of a mile, and longitude within ¼ of a degree, is a somewhat better result than is usually obtained.

Outfit.

Examination of Instruments.—Let every Instrument be tested and its errors determined and tabulated at the Kew Observatory. This is done for a trifling fee. The following are some of the present charges, they have undergone occasional small changes:—Ordinary thermometers, 1*s.*; boiling-point thermometers, 2*s.* 6*d.*; marine and portable barometers, 10*s.*; prismatic compasses, 2*s.* 6*d.*; superior sextants, 5*s.* Unifilars, dip circles, and other magnetic instruments are also verified. The carriage of the instruments to and from the Observatory to be paid. Address—"Superintendent of the Kew Observatory, Richmond, Surrey." The establishment lies ten minutes' walk from the *Richmond* railway station, and is reached through a farm-yard, leading into a large meadow (which is the Old Deer Park). This observatory was established and conducted by the British Association, but is now maintained through a large donation, made by the late J. P. Gassiot, Esq., F.R.S., and is under the direction of a Committee appointed by the Royal Society. Any persons ordering instruments from opticians may direct them to be previously forwarded to Kew for verification, either to the above address, or through the receiving office at the Meteorological Office, 116, Victoria Street, Westminster, S.W.

Packing.—It is difficult to give general rules, because the modes of transport vary materially in different countries. Inquiry should be made by the intending traveller at the Royal Geographical Society's rooms, as to what would be the best for him. The corners of all the instrument cases should be brass-bound; the fittings should be screwed, and not glued; and the boxes should be large enough to admit of the instruments being taken out and replaced with perfect ease. Instrument-makers are apt to attend overmuch to compactness, making as much as possible go into a small solid box, which can easily be put on a shelf; but this is not what a traveller wants. Bulk is rarely a difficulty to him, though weight is; and, above all, it is most important that he should be able to get at his instruments easily, even in the dark. Also a large light box suffers much less from an accidental concussion than a small and heavy one. Thermometers travel best when slipped into india-rubber tubes. A coil of such tubing will serve as a floor, to protect a case of delicate instruments from the effects of a jar. Horse-hair is of use to replace old packing, but it has first to be prepared by steeping in boiling water, twisting into a rope, and, after it is firmly set, chopping it into short pieces. The hairs retain their curvature and act as springs. Instruments travel excellently when packed in *loose, tumbled* cloths.

Sextant for regular work—

A sextant of 6-inch radius, light in weight, by a first-rate maker, divided on platinum, to ten minutes. It should have a movable ground-glass screen in front of the reading-off lens, to tone down a glaring light. (As regards the use of a small level, attached to the arm, see 'Knorre's Method,' &c., p. 16.)

The handle must be large and convenient; the box capacious enough to hold the instrument with its index clamped to any part of the arc, and the receptacle for the telescopes long enough to allow of their being put into the box when set at focus, with their tubes pulled out.

Sextant for detached expeditions, and for taking altitudes when the other sextant is in use for lunars—

A sextant of 3-inch radius, graduated to half-degrees, in a leather case, fitted to slip on to a leather belt, to be worn round the waist, when required.

Mercurial Horizon—

One of the self-replenishing artificial horizons, devised by Captain George, R.N. (p. 20). It is far more convenient to use than the common form of this instrument, and it is accurate enough for ordinary observations of latitude and local time. If the traveller aims at precision, as in measuring base lines by differences of latitude, he should also take with him an artificial horizon of the usual construction. *Reserve:* an iron 3 or 4 ounce bottle of pure mercury.

Watch—

A keyless silver half-chronometer watch, not too heavy, with an open face and a second hand. The hands should be of black steel, long enough to cover the divisions. The divisions should be very clear and distinct. See that the second hand falls everywhere truly upon the divisions. *Reserve:* at least two other good watches; these should be rolled up separately, each in a loosely-wrapped parcel of dry clothes, and they will never come to harm; they should be labelled, and rarely opened. The immediate envelope should be free from fluff or dirt. Covers of chamois leather should be washed before use. Half-a-dozen spare watch-glasses, fitting easily—two to each watch (learn from a watchmaker how to put them in). Three spare watch-keys; one might be tied to the sextant-case, one wrapped up with each watch. *See* p. 23 for further particulars.

Compass—

A prismatic compass, graduated from 0° to 360°.

Two pocket compasses, from 1½ to 2 inches in diameter. The graduations on their cards should run from 0° to 360°, and not twice over from 0° to 180°. A line for True North, temporarily marked on the cards, in the position most appropriate to the magnetic variation at the country about to be visited, may be found convenient. These compasses should be light in weight, have plenty of depth, and be furnished with catches, to relieve the needle from its pivot when not used. The needles should work steadily and quickly: such as make long, slow oscillations are to be avoided. Cards, half black and half white, are recommended. (*See* p. 21 for further particulars.)

Lantern—

To be used with oil, and furnished with a large wick. See that there is abundant supply of air from air-holes in the *sides*; these are essential when the lantern is set upon the ground. Also that all the internal fittings can be removed and cleaned, and that they are solidly made, not merely soldered. It should be furnished with a reflector, to throw a clear light forwards and *downwards*. A good lantern is *most important*. A small ball of spare wick. Oil of the best quality. Wax tapers, for use on detached expeditions.

Thermometers—

Three short and stout boiling-point thermometers, with Casellas' apparatus for boiling them, of the description used by Alpine tourists.

Three ordinary thermometers, which should be graduated from 10° or more below the freezing- to above the boiling-point.

Standard thermometers, at a charge of 1*l*. each, graduated at the

Kew Observatory, may be obtained thence, on the application of any Fellow of the Royal Society, or Member of the British Association.

Aneroids—

Large pocket size (2½ inches across), capable of working without fracture over the highest mountain pass that is expected. Two are required, because simultaneous observations are important. Recollect that such observations, taken even at distances of two or three hundred miles apart, are of value; as the areas are usually very large over which the barometer has nearly the same height at the same moment of time. Aneroids are excellent for most differential observations, but unreliable for absolute ones. They are uncertain at high altitudes.

Memorandum.—Chronometers are designedly omitted from this list, on account of the proved difficulty of transporting them without injury, and the frequent disappointments they have caused, even to very careful travellers. For Barometers, see "*Additional Instruments.*"

Mapping Instruments—

A small case of drawing instruments, containing, among other things, hair-compasses, beam-compasses, drawing-pen, and rectangular protractor.

Protractors: one circular, of metal, of 5 or 6 inches in diameter; one of horn, 5 inches, all graduated, like your compasses, from 0° to 360°.

A graduated ruler of 1 foot or more, in metal; 2 dozen artist's pins. Medium size measuring tape, say 12 yards; pocket ditto, 2 yards.

Stationery—

An artist's board, not less than 8 inches by 13, made of light, well-seasoned mahogany and what cabinet-makers call "framed," to rule and draw upon.

Plenty of good ordinary paper. Note-books (not "metallic," for prepared paper wants strength, and the leaves of such books are very liable to become torn out and lost; they are also damaged by wet).

They should be all of one size, say 5 inches by 3½, or larger. A leather pouch, secured to the waist-belt, having a flap buttoning easily over, to hold the note-book in use.

Two (or three) MS. books of strong ruled paper, foolscap size, each with a leather binding; the pages should be numbered, and journal observations, agreements, and everything else of value, written in them.

A sheet of blotting-paper cut up and put here and there in the ledgers.

Transparent cloth or paper. } For tracing.
Carbonised paper. }

Marquois's scales; for ruling parallel lines at definite intervals.

Blank maps, ruled for the latitudes and longitudes of the proposed route.

Plenty of brass pens and holders; also fine drawing-pens (steel crow-quills) and holder. FH pencils; HB ditto.

Penknives. India-rubber cut up in bits.

Ink-powders of a kind that do not require vinegar. Red ink.

Paints for maps, viz., Indian ink, sepia, lake, cobalt, gamboge, oxgall, in a small tin case.

A dozen sable paint-brushes.

Materials for "squeezes," if travelling where inscriptions may have to be copied. (*See* p. 71.)

Books—

Raper's Navigation Tables; or, in default of these, either Inman's or Norie's.

Weale's Tables are convenient from their compactness.

Shadwell's Cards of formulæ. (Potter, 31, Poultry, London. 2*s.* 6*d.*) Bethune's Tables for Travellers (Blackwood and Sons). With the help of either of these little publications the traveller, who has mathematical knowledge, will thoroughly understand what he is about, and he may dispense with the usual cumbrous navigation tables, confining himself to ordinary tables of logarithms. But we have recommended that all travellers should be furnished with those navigation tables, because they afford at a single reference what otherwise requires additional trouble to obtain.

'Nautical Almanac' for current and future years, strongly stitched in cloth.

Some small Almanacs, such as Whitaker's, contain tables of the position of sun and planets, and of stars to be occulted. One of these is useful to afford what is necessary to take on a detached expedition, the required pages being cut out of it.

More extended barometric tables than are given in this volume, may be procured at the instrument-maker's, or cut out from Guyot's elaborate meteorological tables, published by the Smithsonian Institution, New York.

Celestial Maps (uncoloured) pasted on calico (and learn how to use them).

The best maps of the country you are going to visit, that are to be obtained.

Admiralty Manual for the use of Travellers.

Mem.—Chauvenet's Astronomy (New York, 2 vols.) is one of the most complete and thorough of the mathematical works on geodosy and astronomical observations.

Additional Instruments, not necessary, but convenient.

Theodolites. (*See* p. 29.)

Barometer—(*See* p. 26.)

The mercurial barometer filled by the spiral-cord method when required, as devised by Capt. George, R.N., is on the whole more reliable, and is very much more portable than ordinary mountain barometers. The tubes are carried empty, and the risk of breakage is thereby materially diminished.

Telescope for observation of eclipses of Jupiter's satellites (*see* p. 19). One of 1¾-inch object glass (clear aperture), and of 30 magnifying power, by a really first-rate maker, and well mounted on a stand that can be screwed firmly to a tree or other temporary support may perhaps be sufficient, but a larger telescope, more substantially mounted, is better. In any case, the telescope should be tried on Jupiter, and found to give a satisfactory view of the satellites, before it is taken. Such a telescope might very properly be fitted with a micrometer for the measurement of base lines (*see* p. 19).

Plane table is very useful and almost essential for careful surveys of small tracts of country and for those topographical details which interest an antiquary. That by Lendy is one of the best, and its adjuncts are very complete. It would replace the artist's board mentioned above. The tripod stand that would serve for that, would be useful for other instruments.

Pedometer.

Pocket level (Abney's), with a mirror to show where the bubble is, when it is held to the eye. It also serves as a clinometer for the measurement of slopes.

Maxima and minima thermometers.
Rain gauge.
} For meteorological observations, *see* p. 45.

Extracts from a Letter from JOHN KIRK, M.D., F.L.S., &c.

When Dr. Livingstone and I crossed the mountains and reached Lake Shirwa, our outfit was as follows: one 6-inch sextant, one mercurial horizon, one pocket chronometer, two prismatic compasses, one pocket compass, one field-glass, one aneroid barometer, two common thermometers, two boiling-point thermometers (the brass apparatus commonly supplied is quite superfluous), botanical paper, arsenical soap, one wide-mouthed bottle containing spirits of wine, pocket-lens, knives, note-books, water-colours, mathematical tables, nautical almanac, and wax candles.

The sextant and horizon were under the care of one man. They are on no account to be contained in the same box, partly from the danger of escape of mercury, but more especially to avoid the severe shock which so heavy a weight receives when placed on the ground, or should it happen to strike against a rock or tree; and these are contingencies to be expected. When carried, the limb should be very lightly clamped on the arc. We found no better plan when on the march than having the sextant and horizon fastened to opposite ends of a bamboo or stick, and carried over the shoulders of one of the porters. All the other instruments not carried by ourselves were packed among the other baggage. We read off the sextant by the help of the wax candles, which, from the stillness of the nights, we were able to use in the open air. On a short journey such an outfit is all that can be desired.

Manuscript.

When preparing MS. to be sent home for publication, write each of the natives names *at least once,* in the clearest handwriting you can command. It is best to employ for this purpose the same form of letters that are used in printing. Numerous errors and great loss of time now result in the attempt to decipher proper names written by travellers in their ordinary handwriting only.

Sextant Observations.

The learner must recollect, that although the sextant, almanac, and logarithmic tables taken by land travellers are identical with those used at sea, yet the observations of the landsman and his whole method of ordinary work have quite a different character to those of the navigator. Therefore much will be found in works written for the use of navigators, which the landsman does not want, and, on the other hand, the problems he most requires are not those to which such works give most of their space. This is owing to several reasons, of which the following are the chief:—

1. A sailor is obliged to measure his altitudes from the sea horizon, which is rarely distinct in the night time, and therefore he mainly depends on the sun. The landsman is obliged to measure his altitudes from the mercurial horizon, and mainly observes stars; because the double meridian altitude of the sun is frequently out of the range of his sextant, and a mid-day halt may be inconvenient. The use of stars and the mercurial horizon introduces difficulty on the one hand, and great refinement on the other.

2. In an ordinary sea voyage, the accuracy required for the mapping of a country is of no use; neither could the sailor attain to such accuracy, if he wished it. First, because of the uncertainty of the effects of refraction upon the apparent position of the sea horizon; secondly, because the mercurial horizon gives a double altitude, and therefore double precision

to the result; so that a sextant of 3 inches radius on land has the efficacy of one of 6 inches at sea; and, thirdly, because the unsteadiness of the ship interferes with the free use of the inverting telescope.

3. The sailor carries Greenwich time with him by means of his chronometers. A landsman cannot trust to chronometers. He must find Greenwich time by the independent means of lunars, satellites, occultations, or moon-culminations.

4. Positions in the open sea, that cannot be determined by astronomical observations, are roughly laid down by Course and estimated Distance from the last fixed station. On land, they can be laid down with great accuracy by triangulation.

5. The unsteadiness of the ship makes observation of the satellites, or of occultations of stars, an impossibility to sailors, while they are exceedingly easy and convenient to land travellers.

6. Magnetic variation has to be found constantly at sea, owing to the rapid change of position and the iron in the ships. On land but few, though careful, observations are required (avoiding magnetic rocks).

General Remarks on Observing.—Endeavour with much forethought to *balance* your observations. Whenever you have to take a star's altitude for time east, select and wait, if you are able to do so, for another star as nearly as may be of the same altitude west, and use the same telescope, horizon roof, &c. If a meridian altitude be taken north, choose another star of similar altitude, and take it south; so also with lunars. In this way your observations will be in pairs, and the mean of each pair will tend to be independent of all constant instrumental and refraction errors; and by comparing the means of these pairs, one with another, you will know your skill as an observer, and estimate with great certainty the accuracy that your results have reached. Never rest satisfied with your observations, unless you feel sure that you have gained means of ascertaining the limit beyond which you certainly are not wrong. Weight all your observations; that is, when you write them down, put "good," "very good," "doubtful," &c., by their sides.

Nature of Observations :—

For Latitude—

1. The meridian altitude of the stars or sun is the simplest and safest. Altitudes of stars in pairs, N. and S. of the zenith, at or very near to the

meridian, afford the perfection of accuracy. It is to be understood that several altitudes should be read off, and time noted during the 5 or 10 minutes before and after the meridian passage.

2. The altitude of the Pole-star is a ready method in the northern hemisphere, but only available with an ordinary sextant and mercurial horizon between the N. lats. of about 15° and 60°. Nearer the Equator it is too low for the mercurial horizon, and nearer the Pole it is out of the range of the sextant.

3. By three altitudes of the sun or a star taken near the meridian, at *equal intervals of time*, and not necessarily restricted to the same side of the meridian. (*Chauvenet.*)*

4. When the sky is partly clouded, secure whatever stars you can surely identify, in case the meridian altitude should be lost. Almost any two stars, with the interval noted, are sufficient for the determination of the latitude, by the more or less troublesome calculations described in works on navigation. It is better to observe one or two additional stars as a check against mistake.

For Longitude by lunars, &c.—

Whenever you intend to observe for longitude, make a regular night of it; working hard and steadily, so as to accumulate a mass of careful observations, at a small number of stations.

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* Let a_1, a_2, a_3, be the three altitudes (it is better that none of them should be more than ½ hour from the meridian); A the required meridian altitude; then if

$$q = \frac{[\frac{1}{4}(a_1 \sim a_3)]^2}{a_2 - \frac{1}{2}(a_1 + a_3)},\ q \text{ being expressed in seconds of arc, } A = a_2 + q.$$

The meridian altitude being thus determined, the latitude can be found in the usual manner. (This is a slight but convenient modification of Chauvenet's formula, by Admiral Shadwell.)

(*Example*)

$a_1 = 43°\ 8'\ 20''$ $\quad a_2 = 43°\ 15'\ 30''$ $\quad a_3 = 43°\ 4'\ 0''$

$\frac{1}{2}(a_1 + a_3) = 43\ \ 6\ \ 10$

$a_2 - \frac{1}{2}(a_1 + a_3) = \quad 9\ \ 20 = 560''$

$\frac{1}{4}(a_1 \sim a_3) = \quad 1\ \ 5 = \ 65''$

hence $q = \frac{65^2}{560} = 8''$, and $a_2 + q = 43°\ 15'\ 38''$.

1. Lunar distances. No method is more generally serviceable than lunars. They should be made in pairs, with stars E. and W. of moon, and nearly equidistant from it. Also the thermometer and the barometer (or its equivalent, a thermometer in boiling water) should be noted, and the refraction corrected accordingly; because, if thermometric and barometric corrections be omitted, in observations made on a high and heated plateau, there will be serious errors in the results.

A complete pair of lunars, made wholly by one person, consists of the following observations, *in addition to those for latitude.* None of them may be omitted.

An hour before beginning to observe, get everything in perfect order; see that the lamp is well trimmed, its air-holes free, and that it is filled with oil. Also rehearse the expected observations, that no hitch may occur after they have commenced. Then let the hand and eye have ample time to repose, and go on as follows:—

1. Read thermometer in air.
2. Adjust horizon-glass, if necessary.
3. Two pairs of observations for index error.
4. Three altitudes for time, star E.
5. Three altitudes for time, star W.
6. Five lunar distances, star E. of moon. } A
7. Five lunar distances, star W. of moon. } A
8. Three altitudes for time, star W. } A
9. Three altitudes for time, star E. } A
10. Two pair of observations for index error.
11. Read thermometer in air.
12. Read barometer (or its equivalent, as thermometer in boiling water).

The series A may be repeated over and over again, so long as the eye and hand can be surely depended on.

2. Occultations give the longitude with great accuracy, but those of stars of the fifth and greater magnitudes, which are easily seen with an ordinary telescope, do not often occur. Stars of the sixth magnitude are given in the Nautical Almanac, and are less unfrequent; but it requires a well-mounted telescope, of a larger size than travellers usually care to carry, in order to see them (p. 9). Before your departure, or when you have

leisure, calculate for yourself, or get some one to calculate for you, all the stars you could by any possibility see occulted. Shadwell's Tables for facilitating the approximate prediction of occultations and eclipses at any particular place (Bate, 21, Poultry) are very convenient for this purpose. Out of the list in the Nautical Almanac, only a small portion are available,—the occultation occurring in different latitudes, or when the star is below your horizon, or in the daytime.

3. Eclipses of Jupiter's satellites occur somewhat more frequently than occultations of stars by the moon. They give fair results, and are most convenient to a traveller; for they require no calculation at all, except for local time. But a good telescope, such as that mentioned in the preceding paragraph, and described (p. 9), is required in order to see them.

Notes on Observing with a Sextant. By FRANCIS GALTON, F.R.S.

It may save trouble to others if I mention here the way which, after many trials, I adopted of observing with a sextant. During the daytime I made out a list of the stars that culminated at convenient hours (*see* p. 95), and their expected altitudes. I set my watch to local time by sunset, if it was very wrong, and took care that the minute hand went in correspondence with the second hand; that is to say, that the minute hand was truly over a division when the second hand pointed 0 seconds. If they did not go together, I moved the minute hand till it was rightly set. Then I spread my rug north and south in an open spot of ground, trampling down the bushes and long grass round it. Next, when the time of observing approached, I lighted my lantern and set it on the ground in front of my rug; to this I brought all my instruments, and first spreading a small cloth to the right of the lantern, I set my horizon on it, filled it with mercury, and covered it with a glass. The cloth was to catch any mercury that might be spilled. I then propped up my watch to the left of the lantern, laid down my note-book, with the leaves tied open, and taking out my sextant, adjusted it to the expected altitude, and screwing on the telescope, which always was kept at my focus, I laid myself flat down on the rug. Then taking off the roof from the horizon, if there happened to be no wind, and turning the glare of the lantern away from my eyes, and upon the watch, I made an accurate contact of the star with its reflected image; then looking quickly round, I observed the watch. I now turned the lantern towards me, changed hands with the sextant, read off and wrote down, then turned the lantern back on the watch, and recommenced. For a meridian altitude I read off and wrote down about ten observations, both time and altitude, beginning a little before the star reached the meridian, and continuing after it had perceptibly sunk; it was thus easy to estimate the meridian altitude with accuracy. For greater refinement, in order to measure an important base-line, I occasionally protracted these altitudes, and drew a curved line through them with a free hand, to guide my judgment in estimating the meridian altitude. For lunars, I took time with my second sextant before beginning; also two or three times during the progress of the lunar, and finally at the close of all. I was thus very independent of the good going of my watch, for, by observing every half-hour, no watch that went at all could go far wrong.

KNORRE'S *Method of bringing the Reflection of a Star from the mirrors of the Sextant, into contact with the Reflection of the Star in the Mercurial Horizon.*

In the observation of the altitude of a star with the artificial horizon, it is always troublesome to bring down the image of the star reflected from the sextant mirrors to the image reflected from the mercurial horizon, or *vice versâ*; and sometimes, when two bright stars stand near each other, there is danger of employing the reflected image of one of them for that of the other. A very simple method of avoiding this danger, and of facilitating the observation, has been suggested by Professor Knorre, of Russia. It can be proved geometrically that whenever the direct and reflected images of any star are made to coincide in the field of view of the sextant, the index-glass will be inclined at a constant angle to the horizon. (This angle is equal to the inclination of the sight-line of the telescope to the horizon-glass.) If, therefore, we attach a small spirit-level to the index-arm, so as to make with the index-glass an angle equal to this constant angle, the bubble of this level will play, whenever the two images of the same star are in coincidence, in the middle of the field of view. With a sextant thus furnished, we begin by directing the sight-line towards the image in the mercury; we next move the index until the bubble plays, taking care not to lose the image in the mercury. The reflected image from the sextant mirrors will then be found in the field, or will be brought there by a slight vibratory motion of the instrument about the sight-line.

A sextant is easily fitted up on this principle, the level being made out of a small glass tube of little more than one inch in length. In sextants of the usual construction, the reading-lens is attached to a stem that turns round a short pillar fixed at right angles to the index-arm; in these cases the level may be attached to the same pillar, rotating stiffly round it to admit of preparatory adjustment, and then fixed once for all in its proper position.

Silvering Sextant Glasses—

With Mercury:—The requisites are clean tinfoil and mercury (a hare's foot is handy)—lay the tinfoil, which should exceed the surface of the glass by a quarter of an inch on each side, on a smooth surface (the back of a book), rub it out smooth with the finger, add a bubble of mercury, about the size of a small shot, which rub gently over the tinfoil until it spreads itself and shows a silvered surface, gently add sufficient mercury to cover the leaf so that its surface is fluid. Prepare a slip of paper the size of the tinfoil. Take the glass in the left hand, previously well cleaned, and the paper in the right. Brush the surface of the mercury gently to free it from dross. Lay the paper on the mercury, and the glass on it. Pressing gently on the glass, withdraw the paper. Turn the glass on its face, and leave it on an inclined plane to allow the mercury to flow off, which is accelerated by laying a strip of tinfoil as a conductor to its lower edge. The edges may, after twelve hours' rest, be removed. In twenty-four hours give it a coat of varnish made from spirits of wine and red sealing-wax. It may be as well to practise on small bits of common glass, which will soon prove the degree of perfection which the operator has attained.—(Extract from 'Nautical Surveying,' by Admiral Sir E. Belcher, pp. 9, 10.)

With Silver:—This is a process well understood by many photographers, but requiring materials that no ordinary traveller could obtain.

Observations for Azimuth.—The true bearing of a heavenly body may be obtained by means of a sextant either from observations of altitude or from the apparent time. As the formula for obtaining the latter does not appear in many works on Navigation, it is given :—

Time.	Azimuth.	Month.		Day.		
H. M. S.	° ′		° ′ ″			
		Co. Lat. P. Dist.				
		Sum.				
		Diff.				
		½ Sum.		Cosec		Sec
		½ Diff.		Sine		Cosine
		½ Hor. >		Cotang		Cotang
			Arc 1 = Tang.			
Cor.			Arc 2.			Tang Arc 2
	App. time.					
	Hor. <					
	½		⊙ true Az. (= Arc 2 − Arc 1.) ⊙ mag. Az.			
	½ hor.< in Arc.		Variation.			

NOTE.—Arc. 2 is of the same affection as the ½ polar disc. and Co. Lat.: when one is acute so is the other, and *v. v.*
Add Arcs 1 and 2, when polar disc. is greater than Co. Latitude.
Subtract „ „ less „ „

The angular distance between the Pole-star, which is only 1° from the Pole, and any object on the horizon, affords an approximate and simple method of obtaining the true bearing: the formula for the reduction of the oblique to the horizontal angle is—

Reduction of Angle.

✱ and obj.	Cosine
✱ Alt.	Secant
Red Angle	Cosine

The bearing of the Pole-star at all times, or that of any other celestial object, when near the meridian, affords approximate means of obtaining, without calculation, the variation of the compass.

Base Lines.—By Difference of Latitude—For base-lines the more rapid methods of attainment are alone suitable to explorers in wild countries. None of these measures is more accurate and speedy than that obtained by meridian altitudes of the same heavenly body (star or sun, not the moon) at different stations by the same observer with the same instruments. If the stations are on the true meridian, or nearly so, their difference of latitude is their distance; and if they are otherwise situated, their true bearing and their difference of latitude give the distance between them.

By Micrometer or Sextant, and Short Base—Should the traveller carry with him a good telescope (p. 9), it is advisable that it should be fitted with a micrometer for measuring small angles; care is, however, requisite in seeing that the board or object used for the base is accurately measured, and that it is at right angles to the line of sight. In the absence of the micrometer, the sextant will give a very fair approximation; the angle should, however, be measured both on and off the arc. Rochon's micrometer has been used with great effect in the geological survey of Canada.

Artificial Horizons.

Mercurial Horizon.—Altitudes taken by its means are thoroughly reliable only when the reflections have been observed from the uncovered mercury; for it is difficult to procure glass, large enough for the cover, which does not sensibly distort the reflections. The errors introduced by the interposition of glass may be partly got rid of by reversing the cover between each pair of observations.

When observing for "equal altitudes," morning and evening, be sure that you have the same face of the cover opposite to you on both occasions. One of the faces of the cover should be marked for this purpose.

The trough should not be less than 3½ inches inside length, because the convex border of the mercury is useless, and the surface of the central portion is foreshortened to the observer.

Captain George's Horizon.—A very ingenious, small, and handy mercurial horizon has been contributed by Staff-Commander George, R.N., formerly Curator of Maps at the Royal Geographical Society, and is made by Messrs. Gould and Porter, successors to Cary, optician, No. 181, Strand. It consists of a disc of glass floating on mercury, in a vessel which it nearly fits, and it has an arrangement (applicable also to the common mercurial trough) by which the mercury is introduced, ready filtered, from an attached reservoir, and afterwards withdrawn, in a manner that saves a great deal of trouble. The glass floats without touching the sides of the trough, and the whole of the mercury below it is serviceable. A very small trough on this principle gives as wide a field of view as a large trough used in the ordinary way. There is yet another advantage, in that the reflection of the glass causes its under-surface to be optically raised; therefore the edges of the trough cut off proportionately less of the field of view. Also, at very low altitudes, the reflection from the upper surface of the glass, which may rise above the edges of the trough, becomes so bright as to materially reinforce, and even supersede, the reflection from the mercury below. Hence very low altitudes may be observed with this instrument. It has, besides all this, the great advantage of a peculiar steadiness, both when people are walking near it and during wind.

As regards its accuracy, when the glass is of the best workmanship, the *mercury pure*, and its surface quite clean, the results leave nothing to be desired; but, unless these conditions are *scrupulously observed*, errors of five, or more, minutes in the double altitude, or of half that amount in the single altitude, may be easily introduced. Its glasses should be examined and approved before it is taken.*

Before introducing the mercury into the trough, cleanse the trough thoroughly from dust, which will otherwise rise to the surface of the mercury, and, when setting the glass afloat, take exactly the same pre-

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* If the traveller should ever doubt the performance of one of these horizons, he may easily test its accuracy by means of any telescope mounted on a stand, and furnished with cross wires. He should direct the telescope down towards the mercury and intersect with the cross wires the reflection of some clearly defined fixed point; then reverse or otherwise disturb the horizon, and, after it has again settled to rest, observe whether the cross wires continue to intersect the reflection of the same point. The point selected should be at many yards' distance from the observer, else, if the level of the mercury happen to be raised or lowered during the trial, the results would be sensibly vitiated.

cautions as in silvering sextant glasses (*see* p. 17), by putting paper or thin silk first on the mercury, and the glass upon that, and then carefully withdrawing the paper from under the glass.

Compasses.

Prismatic Compass.—The prismatic compass is one of a traveller's most useful instruments. Its graduations should be engraved on an aluminum ring, on account of the sharpness of the divisions and the lightness of the material, and its greater power of withstanding the effects of heat and wet than an ordinary card. When using it, if you have no tripod, make a pile of stones and lay the cover of the compass on the top, with its bottom upwards; this makes a smooth table for the azimuth compass itself to be moved about on. Be on guard against magnetic rocks; it may happen that the bare peaks of high hills, which are the best of places for observing from, and which a traveller often makes great sacrifices to reach, will be found so magnetic as to render compass observations worthless. A small sextant should always be taken up on these excursions. It is of little use in a wild country to devote much time to getting accurate bearings, as the landmarks themselves are rarely well defined: the main endeavour should be not to mistake one hill for another, to judiciously select good angles, and to carry on more than one independent scheme of triangulations at the same time, by comparison of which the accuracy of the whole may be tested. It is surprising how much work may be thrown away by want of judgment; and also how much may be done, with very little trouble, by a person who has acquired a good eye and memory of country.

It is, perhaps, hardly necessary to call attention to the fact, that in prismatic compass-cards the south pole of the magnet is placed under the 360°, and the north under the 180°, because in these instruments the reading is from the nearer edge of the card towards its centre, whereas in an ordinary compass the reading is from the centre of the card towards its outer edge. It follows from this that the same compass card cannot be used indifferently with or without a prism. Moreover the figures intended for use with a prism, have to be drawn not like ordinary figures, but like figures seen in a looking-glass, in order that the reflection in the prism may show them in their proper position.

Pocket Compasses.—The patterns on these cards have been greatly improved of late years. Until recently it was scarcely possible to meet with a compass capable of being read in a dim twilight, which is just the time when its easy use is of most importance to a traveller. A representation of perhaps the most legible form of card in a faint light is given here.

The better cards are made either of talc covered with paper, or of mother-of-pearl.* Both of these materials are heavy, and their weight, of course, tends to injure the point on which they turn, especially if they happen to receive a jar when they are resting on the point, and also to make their oscillations sluggish. These disadvantages are, however, less

* A disc of aluminum foil, procurable at Johnson, Matthey, & Co., 77, Hatton Garden, London, is only one-ninth part the weight of a mother-of-pearl card of the same size. It seems equally good as regards durability, and it can be shaped and lettered in any desired manner by embossed stamps or by perforations. But I have not yet succeeded in fashioning it into a clearly legible card. Perhaps some instrument-maker may be more successful.

Mem.—To read a compass or a watch in the twilight, when it is a little too dark for unaided vision, *use a strong magnifying glass.* Its effect in giving distinctness is extraordinary.—F. Galton.

serious than those that attend the use of a common card, which warps with heat, and is spoiled by a wetting.

A pocket compass suspended on gimbals comes to rest much more quickly than one that is held in the hand. This advantage is specially noticeable when it is growing dark, and when consulted on the side of a hill, for in either case it is difficult to judge of horizontality. It is most important to a traveller, whose caravan is on the march, that he should lose very little time when he is consulting his compass.

Watches.

By John Coles, *Curator of Maps, R.G.S.*

The keyless half-chronometer is the most suitable watch for a traveller in wild countries. (The half-chronometer watch is a lever watch, with compensation balance, and a carefully tempered pendulum spring.)

The ordinary pocket chronometer is expensive, and not calculated to stand the rough usage to which most travellers' watches are subjected. The objections to it are: (1.) The extreme delicacy of the escapement, and liability to injury from rust or accident. (2.) Its great liability to stoppage from various causes, such as a sudden jerk when riding or travelling over a rough country; even if in the act of winding it the holder should inadvertently give a circular motion to his hand in a direction opposite to that in which the balance-wheel may be moving at the same instant, it may stop. (When a chronometer is once stopped it will not start again unless a circular motion be given to it.) (3.) The impossibility of its repair when injured, except by highly-skilled workmen, and when very slightly injured, the consequent great disturbance and irregularity in its rate.

Under favourable circumstances, and in skilled hands, pocket chronometers have done good service, but this is exceptional. The minimum price of a good pocket chronometer, in a silver case, is 45*l*.

Half-chronometers are not liable to stop from the before-mentioned causes, unless from rust of an aggravated kind. They are more easily repaired. They may be carried in the pocket under conditions of rough usage, short of actual violence, and under those circumstances they may not fall far short of a chronometer at rest in the regularity of their rates.

During the last twenty years great improvements have been made in the manufacture of the lever escapement compensation balances and the pendulum springs, upon which the ability of a watch to keep a steady rate in a great measure depends; the keyless mechanism has also been perfected, and it is not necessary to open the case of a keyless watch in order to wind it, or to set the hands, thus the works receive increased security from dust and damp, the two great enemies of all timepieces.

The following is the description of such a watch as would be best suited to a traveller. The watch should be a 16-size silver case half-chronometer; the bezel (or frame which holds the glass) should have neither hinge nor spring, but should fit very closely over the watch-case, and snap tightly when pressed home; great care should be taken to see that the marking of the minutes on the dial is correct, so that in whatever part of the hour circle the minute hand shall point to a division, the seconds' hand shall at the same time point to 0. This perfect coincidence is by no means common; its absence is chiefly due to eccentricity in fixing the dial-plate, and the error is often so great as to be a cause of great annoyance to the traveller, who will have frequent difficulty in deciding as to which minute the seconds belong. The seconds dial-plate should be sunk, and the glass should be thick flat crystal. A good watch of this kind cannot be purchased for less than 20*l.*

The keyless watch has many advantages over the old form, of which the following are some. It cannot be wound the wrong way. It cannot be over-wound. The case has not to be opened either to wind it or to set the hands. With screw caps to cover the push-bar and the winding-button, a watch of this kind has been placed in water, and proved impervious to damp after several hours' immersion. Should the winding mechanism get out of order, the watch can be wound with a common key in the same manner as an ordinary watch. The cost of a good watch of this description is 30*l.*

Care should be taken to wind a watch at about the same hour every day, and as nearly as possible to subject it to the same daily treatment, with regard to its position in the pocket, or the place where it is laid down at night.

In purchasing a watch be sure to go direct to the manufacturers, as such watches as I have mentioned can only be obtained of the best makers. Cheaper watches, purporting to have compensation balances and the best pendulum springs, may be obtained from many shops; but it will too often be found (when too late to replace them) that they are not all they profess to be, that they have never been properly adjusted, and are in consequence so affected by change of position and temperature as to be useless for scientific purposes.

On Carrying Chronometers. By Admiral Sir GEORGE BACK, F.R.S.

It is impossible to avoid jolting pocket chronometers or watches when worn about the person.

On three Arctic (overland) expeditions, mine (frequently two chronometers) were suspended in cloth pockets, hung round the neck by a strong narrow silk ribbon, and kept in their places by two other ribbons tied round the waist; the whole was secured by the waistband of the trousers, which was made with six holes (three on each side), to lace behind. A silk string, passed through eyelet-holes round the top of the pocket and tied, secured the chronometer in its place, and prevented wet and dirt from reaching it.

When travelling in summer, the chronometers were taken off at night and placed carefully in a hat, horizontally, or else in some blanket, under the upper part of the blankets forming the bed, where they were more out of the way of accidents; but in winter they were worn all night against the body, to protect them from the effects of the cold.

We (Franklin, Richardson, Kendall, &c.) never complained of finding "fluff" in the cloth pocket, and I do not know of an instance of the chronometers getting wet.

Franklin fell between two pieces of ice into the water, over-head, and sunk fully two feet, and the two chronometers were not injured.

I do not recommend "Macintosh" for the pockets. In cold, *freezing* weather, our Macintosh cloaks became stiff as planks; and in very sultry weather, portions of the caoutchouc oozed through. Common linen or washed chamois leather would do for lining.

On a Composition for keeping Watches or Compasses watertight.
By JAMES BROCK.

The method that I should recommend for preventing water from penetrating watch-cases, is the application of a preparation of beeswax and resin to the several parts where it is possible for the water to pass. The preparation I recommend should be composed of equal parts and well mixed. If it is for a very hot climate, the quantity of "resin" should be slightly increased. It may be kept prepared, and when wanted, a portion melted and applied to the several parts with a small brush or feather. If the watch is an ordinary *Open-face,* with a SNAP bottom, the parts that should be attended to are—1st, the glass. Apply the preparation round it, and rub it in with the thumb, by which means it will be worked into any cavity. 2nd, open the glass and apply it round the part of the case upon which the glass shuts (be careful that you apply it to all the joints of the case), close the glass and squeeze it down tightly; what is squeezed out may be cleared away with the nail or a piece of wood. 3rd, open the back (where the watch is wound up) and apply the preparation in the same manner as just named. The case will require a little more force to open it, and the back should be attended to frequently. If the watch has a *hunting* (or double) case, or a *bottom that opens with a fly-spring,* the difficulty of keeping out the water is much increased, as there are so many openings into the case for the springs, &c. I should recommend that the springs be removed (which is easily done, as they are all screwed in), and that the holes through which they pass, also the *screw holes,* be stopped up with the preparation; also *remove* the *push-piece* from the pendant (this is done by taking out the screw, which passes through the bow), and stop up the hole from which it has been taken; but care should be used in doing so, as it is essential that it should be stopped *below* the hole through which the screw of the bow passes. The bow may then be returned, The preparation should now be applied to the glass and the shutting parts, in the manner before described. The hunting cover will keep shut by nature of the preparation.

BAROMETERS AND THEIR SUBSTITUTES. (*See* Tables pp. 97–104.)

The travellers for whose use these remarks are prepared, being possessed of sextants or theodolites, would measure the heights of mountains above their bases by triangulation from a distance. But they also require, for the purposes of physical geography, to ascertain the height of the country where they are travelling, above the sea-level; and whenever they have to observe lunars on elevated plateaux, a knowledge of the barometric correction for refraction is essential to them. For these latter purposes, explorers must have recourse to barometers, or to their more or less imperfect substitutes.

A single barometric observation made in regions where the barometer ranges, as with us, through two or more inches, even in ordinary weather, is unreliable to half that extent, that is, to more than 1000 feet, in calculating altitudes: but the mean of several observations taken at chance intervals, at repeated visits, and during ordinary weather, is not likely to be far amiss. In tropical regions the barometer is very much more steady than with us, and the heights deduced from the observations of travellers are proportionately more to be depended on.

If a second station can be established, for simultaneous observations, at 100 or even at 200 miles' distance, their relative heights can soon be determined with some accuracy by the barometer, because the meteorological waves are so broad, that there is seldom a difference, in ordinary weather, even in our latitudes, of a quarter of an inch (or say 250 feet of calculated altitude), between two stations 100 miles apart.

The readings of barometers and boiling-point thermometers, when they are erroneous, nearly always err in the direction of assigning too great elevations, because the barometer, when either air or damp gets into the tube, becomes depressed, and the thermometer, when heated by imperfectly-boiling water, stands lower than it should.

The barometric instruments are,—

1. *Barometer.*—Empty glass tubes can be carried with little risk, and they can be filled with mercury when required by the spiral-cord method of Captain George, R.N., and be set up and used temporarily as barometers. The method of doing this is described in the pamphlet with which the instrument is accompanied.

2. *Aneroid.*—An excellent instrument for laying down the contour lines of a country, but quite unreliable for absolute heights, unless checked by a barometer or boiling-point thermometer, because its index error is apt to change to any amount without the traveller being otherwise able to ascertain, much less to make a just allowance for, the change.

3. *Boiling-point Thermometers.*—These have the great merit of portability without risk, and of a pretty constant, but not absolutely constant, index error; consequently, they are largely used by travellers. Though the operation of boiling a thermometer is very simple on a table in a room, with the use of spirits of wine, it is very troublesome in the open air over

an ordinary camp fire. Apparatus, to be used with spirits of wine, is made by Casella, 14, Hatton Garden. A small "Russian furnace" is by far the most powerful kind of spirit-lamp, and the best for out-of-door work; it consumes no more spirit than the common lamp. Colonel Grant, who had, together with Captain Speke, great experience in the manipulation of these instruments, speaks very highly of the effectiveness of the boiling-apparatus which he took with him from the Geographical Society, and which was fitted into the bull's-eye lantern he used for reading off his sextant at night. The "shade" was removed out of the lantern, and the boiling-apparatus was put into its place. It was a copper cup, set in a jacket pierced with air-holes. An horizontal tube with a screw nozzle pierced the side both of the jacket and of the cup, and the thermometer was passed through this tube. The thermometer passed through a cork fixed into the middle of a screw which was screwed into the nozzle. It requires, however, very careful trimming of the lamp to obtain sufficient heat to boil the water thoroughly. No compact apparatus can as yet be recommended fit to be used with a lamp fed with common oil, which shall act with certainty in the hands of an average traveller. It is essential to accuracy, and also to the steadiness of the mercury in the thermometer, that its bulb should not touch the boiling water, but be thoroughly enveloped in the steam which issues copiously from it.

A tin pot, with a sliding tin cylinder inside, with holes for escape of the steam, and which admits of being pegged at the desired height, may be used when a common fire is the source of heat. The thermometer is passed through a cork which is pressed into a hole in the lid, which fits firmly (like the lid of a pill-box) on the top of the inside tin cylinder. The fire must be made of bright clear embers to avoid trouble with smoke, and the pot must be securely propped on stones or hung like a gipsy kettle, for fear of a fall and of the destruction of the thermometer.

The thermometer should be observed after the water has been boiling freely, but not too tumultuously, for three or four minutes; and at least four or five readings should be taken, at half-minute intervals. Though pure water ought to be used, yet any water that is not very hard will suffice for a traveller's ordinary need.

Tables for the determination of heights from the boiling-point thermometer and from the barometer will be found in p. 98.

ON OBSERVATIONS WITH THEODOLITES OR ALTAZIMUTH INSTRUMENTS. By Colonel J. T. WALKER, R.E., F.R.S., Superintendent of the Great Trigonometrical Survey of India.

In the opening pages of these Hints, lists of instruments have been given which travellers of little experience are recommended to provide themselves with, and the sextant has been more particularly recommended, as the traveller will have opportunities of practising with it under the tuition of the officers of the ship which is conveying him to his destination. The suitability of this instrument for observations, both on land and sea, is thus a great advantage for any person who has not had an opportunity of learning the use of his instruments before starting on his expedition; and should he not have a sufficient knowledge of the methods of reducing the observations and calculating the results, he will find the simplest and easiest rules for his guidance in the several works on navigation, which are specially written for the reduction of observations with sextants by persons possessing little or no knowledge of the principles on which the rules are based. The inexperienced traveller can scarcely be expected to attain much accuracy in his observations and reductions, but should he explore unknown regions, he may be able to acquire valuable information, the immediate interest of which may be very considerable; but his work will necessarily be of a preliminary nature, and be liable to be largely corrected, or altogether superseded, by the operations of subsequent explorers.

But the extent of the regions of *terra incognita* in which inexperienced travellers can operate with the greatest advantage is constantly becoming more and more narrowed and diminished, and geographical science now-a-days frequently requires that the rough outlines which have hitherto sufficed for her purposes should not only be amplified and filled in, but rectified by more exact and reliable observations. The traveller must, in such cases, be provided with an instrument of greater capabilities than the sextant, and he should have thoroughly learnt the use of this instrument and the method of reducing the several kinds of observations which may be made with it before he commences operations. If he has no better instruments nor greater skill than his predecessors, his results may differ widely from theirs, but they will not be more worthy of confidence, and, while causing much perplexity and inconvenience to geographers, they will only exhibit with certainty the degree of uncertainty that is still attached to the problem under investigation.

An altazimuth instrument—or a theodolite possessing a complete vertical circle as well as a horizontal circle—is in many respects superior to a sextant. 1st, it measures horizontal angles directly, thus avoiding the labour of reducing oblique angles to the horizon; and a round of several angles can be measured with far less trouble than with the sextant: 2ndly, it measures small vertical angles of elevation or depression of objects which frequently could not be seen by reflection from a mercurial horizon for the measurement of the double angle by a sextant. 3rdly, its telescopic power is usually far higher than that of a sextant. 4thly, it may be so manipulated as to eliminate the effects—without in the first instance ascertaining the magnitudes—of certain constant instrumental errors, such as excentricity, collimation, and index errors. And 5thly, the influence of graduation errors may—when great accuracy is required—be reduced to a very considerable extent by systematic changes of the zero settings of the horizontal circle.

The disadvantages of the altazimuth instrument as compared with the sextant are its greater cost and bulk and weight; but in many instances these disadvantages will be more than counterbalalanced by its superior capabilities.

Messrs. Troughton and Simms have favoured me with the following details regarding the cost, weight, and telescopic powers of these instruments as constructed by themselves:—

Instrument.	Weight of with Box.	Weight of Stand.	Price.	Telescopic Powers.	Readings of Verniers.	Details.
	lbs.	lbs.	£ s. d.			
7-inch (radius) sextant	7		12 0 0	5 to 10	10″	
Artificial horizon ..	5 to 10					
4-inch (diameter) transit theodolite	13¼	9	23 0 0	9 „ 12	1′	Without transit axis level, and lamp.
5-inch „ „ ..	25	10	32 10 0	11 „ 15	30″	With transit axis level and lamp.
6-inch „ „ ..	31	10	40 0 0	12 „ 18	20″	Do.

The Messrs. Casella construct certain very light and cheap altazimuth instruments, with 3-inch circles, power 5, weight with box 4 lbs., weight of stand 3½ lbs. divided to 1′, price under 20*l*.

For astronomical observations the sextant is decidedly preferable to very small altazimuth instruments, but the latter are to be preferred for the measurement of horizontal angles and small elevations or depressions.

The traveller must necessarily adapt his equipment to his requirements and the facilities he will possess for carrying his instruments about. He may find it convenient to employ a sextant for astronomical, and a very small light altazimuth for terrestrial observations. But, whenever practicable, an altazimuth of moderate size, which may be used as a universal instrument, would undoubtedly be the most convenient and satisfactory.

The instrument which I would recommend for astronomical explorations, as being well adapted for astronomical and for terrestrial observations, and not very bulky, is the 6-inch transit theodolite by Messrs. Troughton and Simms: several of these have been used in explorations connected with the operations of the Great Trigonometrical Survey of India, and have given great satisfaction, being sufficiently accurate for all desirable purposes, and not too heavy to be easily carried. These instruments are adapted for determinations of time and longitude by the method of zenith distances, and also by that of meridional transits; the former being best suited for the traveller when he can only devote a few hours to the operations, the latter when he is halting for a long time at one place: the two methods lead to strictly independent results, so that when both are employed they serve to check each other. The instrument is also well suited for latitude and azimuth observations; in fact it can be employed in any of the investigations which an explorer may have to undertake by means of astronomical observations. On the other hand, as an instrument for the measurement of terrestrial angles, whether horizontal or vertical, it is very valuable, and far superior to any sextant, not only being more conveniently manipulated, but possessing telescopic powers which permit of the detection and identification of objects that would often be sought for in vain with a sextant.

Trigonometrical operations are, as a rule, far simpler and more easily reduced, and lead to more accurate results than astronomical observations. A continuous triangulation, or a traverse with measured angles and distances, is necessarily impossible when the explorer has to pass through a country very rapidly; but he may frequently remain for several days at one place, and may then have opportunities of greatly extending the scope of his operations by executing a triangulation. Suppose him to be in view of a range of hills which he may not have an opportunity of exploring, distant say 50 to 100 miles; he may have already endeavoured on his line of march to fix points on the range by bearings, but from the absence of prominent landmarks has found a difficulty in identifying the points observed, and thinks he may have mistaken one hill for another in consequence of their changes in appearance as viewed from positions at some distance apart. If, during his few days' halt, he can manage to do a little triangulation, he may fix the general outlines of the entire range relatively to his halting-place with very respectable accuracy. He has first to measure a base and determine by triangulation the positions of three stations lying in a direction nearly parallel to that of the range, and at distances of 2 to 5 miles apart; then at each of these stations he must measure the angles between the other stations and a series of points on the entire length of the range; * though no very prominent landmarks may be visible, still the telescope will show a number of objects—trees, masses of rock, and peculiarities of the ground—sufficiently clearly to permit of their being recognised at stations of observation which are so close to each other; and though the triangles will be very acute-angled, the angles may easily be measured with sufficient accuracy to give the

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* He should make a sketch of the outline of the range in his book of observations; and as he will probably be unable to ascertain the names of the hill summits at such a distance from them, and many of them may have no names, he had better number them in the order in which they are observed, and refer to them always by these numbers, until he can confidently replace a number by a name. Exaggerated sketches of the outlines of the objects intersected by the telescope are frequently of use to facilitate identification on proceeding to the next station.

The positions of places situated within or beyond the range of hills, which are invisible to the traveller, but are known to his native guides and assistants, may frequently be determined by making a native point the theodolite, as a gun, in the direction of the place, and state its distance beyond or on this side of the range. The guides will often be found to possess a remarkable knowledge of locality, and I have frequently known the independent pointings of different men towards distant invisible objects to coincide together very closely, as was shown by the readings of the azimuthal circle.

distances of the points on the ranges from the stations of observation with a small percentage of error, whenever the marks are fairly identified; and as there will be two triangles to each point, and, therefore, double values of the side common to both triangles, any mistakes—whether of identity, or of reading, or calculation—will be at once shown up.

The 6-inch transit theodolites of the Indian Survey which have been used in military expeditions and explorations are specially provided with a pair of micrometers in the eyepiece of the telescope, for the purpose of measuring small angles, and more particularly those subtended by objects of known dimensions, by means of which the distance between the object and the observer is readily deduced. The system of micrometers is movable through an angle of 90°, so as to permit of the measurement of either a horizontal or a vertical object. With the aid of this appliance, the instrument can be employed in carrying on a traverse without using any direct measuring apparatus, such as a chain or perambulator, the distances to the back and forward stations being determined by measuring the angles subtended by poles of known length, which are set up at the stations. In hilly and broken ground, in crossing rivers or other obstacles, and generally wherever a direct measurement is impracticable, this method of procedure is most convenient. It was adopted by Captain Carter, R.E., in his survey—with one of these instruments—of the line of country passed over by the British army in the Abyssinian expedition. Captain Carter carried a traverse from Adigerat to Magdala, a distance of nearly 300 miles, without any break of continuity, the daily rate of progress averaging 5 miles, and being occasionally as much as 8 miles. The difference of latitude between the origin and terminus as determined from these operations only differed by about a quarter of a mile from the value determined astronomically.

Whenever a halt occurred in the movements of the army, the instrument was used as a theodolite in triangulating to fix the positions of all hills and other prominent objects around the halting-place; it was also used for various astronomical observations.*

* These instruments being furnished with a pair of micrometers, which can be used either horizontally or vertically, are all the more valuable for astronomical observations; for the micrometers give two additional wires over which the stars may be observed, and these wires can be set at pleasure to any distance from the

Remarks on the Manipulation of Altazimuth Instruments.

Observations with these instruments should always be made in pairs, with the face of the vertical circle alternately to the right and left of the observer. Thus, supposing that in the first observation, or round of observations, the face of that circle is to the right of the observer, the telescope should be immediately afterwards moved through 180° in azimuth, and turned over in altitude, which will bring the face of the circle to the left of the observer, and then a second observation, or round of observations, should be taken; the mean of the two measures, face right and face left, will be free from collimation, index, and other instrumental errors.

In measuring horizontal angles between objects of nearly the same altitude, as landmarks not much above or below the horizon, a change of face is not absolutely necessary, and may be dispensed with if the observer is hurried; but when such angles are measured between objects of very different altitudes—as a terrestrial referring mark and a star—and whenever altitudes are measured, whether of terrestrial or celestial objects, the observations should invariably be taken in both positions, alternately "face right" and "face left," and the final result deduced from the mean, in order that the instrumental errors may be eliminated. There is no necessity to determine the magnitude of these errors, as in the sextant; in an instrument which has to travel far over bad ground the adjustments are liable to alter from time to time, but they are not likely to alter in the interval between two consecutive observations, and the errors arising therefrom will be eliminated in the mean of the pair.

In what follows regarding *astronomical* observations with these instruments, a complete observation will be understood to imply the mean of a pair of observations, one with face right, the other with face left, taken continuously without any considerable pause between them, the entire operation being considered as one observation.

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fixed wires in the diaphragm which may be best suited to the rate of movement of the star. For pairs of observations—face right and face left—no reductions to the centre wire are necessary; and thus greater accuracy is obtained with very slight additional trouble of observing, and still less of computing.

Determinations of Time, Azimuth, Latitude and Longitude, with a Transit Theodolite.

The transit theodolite may be employed either as a transit instrument or as an altazimuthal instrument; it is adapted for all astronomical observations, excepting those of "lunar distances," which can only be performed by a sextant or a reflecting circle, and occultations, which require larger telescopes.

Thus a description of each of the various kinds of observations which can be made with transit and altazimuth instruments, with full details of the methods to be employed in the corresponding reductions, would fill a volume, and be much more than is required for a book which merely purports to give hints to travellers. Those who wish to learn full particulars of each of the several methods of observation, and of the reductions, cannot do better than study Chauvenet's 'Spherical and Practical Astronomy,' which is one of the most valuable works on the subject in the English language: it gives ample instructions for observations of all kinds, the rudest and most hurried, as well as the most refined and elaborate, and it supplies corresponding formulæ—approximate as well as rigorous—for the reduction of the observations.

As these Hints are merely intended to indicate the simplest and most expeditious methods by which a traveller who is able to carry a suitable altazimuthal instrument about with him can take the astronomical observations which are essentially necessary for his geographical explorations, they will be restricted to determinations of time, latitude and longitude, by the measurement of zenith distances, and of azimuths by horizontal angles; formulæ—some approximate but all sufficiently rigorous for the purpose, and adapted mostly from Chauvenet—will also be given, for the reduction of the observations.

Latitude Observations, the time being unknown.—The instrument being duly levelled and brought approximately into the meridian, set the telescope on any star—or on the sun—when approaching culmination, and follow it until the maximum altitude is reached; take the zenith-distance reading on the vertical circle, change face quickly, and make a second observation; the mean of the two will be a "complete observation" of zenith distance. Two or three pairs of observations may be taken to circumpolar stars, as their zenith distances will not alter sensibly during an interval of a quarter to half an hour; for other stars the observations should be restricted to one pair, and stars should not be observed when within 25° of the zenith. A single pair of observations with the 6″ transit theodolite should give a determination within 20″ of the truth; greater accuracy may be obtained by observing additional stars, more particularly when the stars are selected so as to form pairs of nearly equal distance from the zenith, north and south.

Latitude Observations, the time being known.—(1.) Observe the zenith distance of the Pole-star in any position, and reduce to the meridian by the tables in the 'Nautical Almanac.'

(2.) Take circum-meridian observations of the zenith distance of any star, alternately face right and face left, and note the time of each observation; compute the reduction of the zenith distance at the time of observation to the distance on the meridian, and take the mean of the reduced results as the determination of the meridional zenith distance. Three or four pairs of observations may generally be made in succession to the same star; but the nearer the star is to the zenith the more accurately should the times be known—it is not desirable, therefore, to observe stars within 10° of the zenith. Here, too, pairs of north and south stars of nearly equal zenith distance will give the best results.

Time.—Take pairs of observations of the zenith distance of a star, noting the chronometer time of each; and adopt the mean of the times as the time corresponding to the mean zenith distance, with which, the latitude of the place, and the star's declination, the star's hour angle must be computed by either of the well-known formulæ: thus the local time and the chronometer error will be determined. For these observations stars are most favourably situated which are easterly or westerly, and not very near either to the horizon or to the meridian; and greatest accuracy is obtained when two stars are observed at nearly the same altitude, one to the east, the other to the west. With a pair of observations the chronometer error should be determined within 1 second when a 6″ transit theodolite * is used.

* At a trial of one of these instruments for the Indian Survey, the results of six pairs of observations on east and west stars fell within an extreme range of 0·4 of a second of time; the stars were, however, observed on the wires of the two micrometers, as well as on the fixed wire of the diaphragm. (*See* footnote, page 33.)

Longitude.—Take pairs of observations of zenith distance on a star for the determination of the local time and chronometer error, then take other pairs of observations of zenith distance on the moon; in each instance adopt the mean of the chronometer times as that of the "complete observation" of zenith distance. Both moon and star should be easterly or westerly, and not very near either to the meridian or to the horizon. The operations should commence and close with star observations, in order that the chronometer rate may be duly ascertained and allowed for. Ten pairs of observations to the moon and six to stars ought not to occupy more than four hours, and they should give a very fair result, probably within 8 miles of the truth. The effect of instrumental errors will be materially reduced when the stars and the moon are on the same sides of the meridian and at nearly the same zenith distance; if time permits, observations should be taken both east and west of the meridian, and both before and after full moon.

Azimuth, time and latitude being unknown.—Observe the angles between a referring mark * and a star when the star is at the same altitude east and west of the meridian; several pairs of observations may be taken at consecutive altitudes, half with face right and half with face left. Or the angles may be measured between a referring mark and a circumpolar star at the times of its maximum elongations east and west. The mean of the two angles at opposite positions gives the angle between the star and the meridian, and thence the azimuth of the referring mark, without any calculations whatever. In the first case, however, an interval of several hours must be allowed to elapse between the observations east and west; and as twelve hours must necessarily elapse between the opposite elongations of a circumpolar star, few stars will ordinarily be visible at both elongations.

It may therefore be desirable to adopt a third and more expeditious

* A good referring mark may be made of a cross with a hole of ¼ to ½ an inch in diameter in the centre, to which observations can be taken by day and by night, being rendered visible at night by a bull's-eye lantern placed behind the hole and directed to the observer. The stem of the cross should be vertical, and driven firmly into the ground. The distance from the station of observation should be at least half a mile, and the station should be marked by a pin driven into the ground, over which the theodolite must be carefully centred whenever set up for horizontal observations.

method, as follows:—Measure the angles between the referring mark and *two* circumpolar stars at their respective elongations, selecting stars which are nearly in opposition or nearly in conjunction, and will attain their maximum elongations at nearly the same time, that the observations may be completed quickly; then with the observed value of the angle between the stars, and the given declinations of the stars, the azimuths of both may be readily computed, as shown at page 42.

Azimuths, latitude being known.—Observe the angle between the referring mark and a circumpolar star at maximum elongation, and compute the azimuth of the star. To stars near the pole two or three pairs of observations, face left and face right, may be taken before the star moves sensibly from the position of maximum elongation.

Azimuth, latitude and time being known.—Any star may be observed in any position, but the best results will be obtained when a circumpolar star is observed at a short distance from the elongation; the angle between the position of the star at the observation and at the elongation may be computed by the formulæ at page 42.

General Remarks.—The observed zenith distances should always be corrected for refraction; barometer and thermometer readings should, therefore, be taken during the observations, for the better determination of the refraction. When no barometer is at hand, the height of the station of observation should be given, as deduced by the boiling point or otherwise, or even approximately estimated. It may be well to remember that in determining latitude errors of refraction may be eliminated by observing pairs of north and south stars of the same zenith distance.

Formulæ and Examples.

Latitude by Circum-meridian Obervations of a Star.

Let ϕ be the true latitude, ζ the true zenith distance on the meridian, ζ^0 the observed zenith distance corrected for refraction, δ the declination of the star,* ϕ_0 an approximate value of $\phi, = \delta \pm \zeta_0$, t the hour angle of the star.

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* When the sun is observed, the declination corresponding to the mean of the times of observation should be used.

$$\text{Put } A = \frac{\cos\phi_0 \cos\delta}{\sin\zeta_0} \text{ and } m = \frac{2}{\sin 1''} \sin^2 \tfrac{1}{2} t.$$

$$\text{Then } \zeta = \zeta_0 - Am, \text{ and } \phi = \delta \pm \zeta.$$

The values of m are tabulated in Chauvenet's 'Astronomy.'

Alternative forms of m, adapted for various logarithmic tables.
- $m = \operatorname{cosec} 1'' \operatorname{versin} t$.
- $= \cdot 00055 t^2$, when t is given in seconds of time.
- $= 2\, t^2$ nearly, „ „ minutes „

Supposing n observations to be taken, then, since A is constant,

$$\zeta = \zeta_0 - A \frac{m_1 + m_2 + \ldots + m_n}{n}.$$

Example.—Circum-meridian Observations for Latitude to β Ursæ Minoris, North of the Zenith.

Face.	Circle Readings.*	°	′	″	Mean Zenith Distances of Pairs of Observations. °	′	″	Chronometer. H.	M.	S.	t in Minutes of Time.	t^2.
Left	Alt.	64	10	20	35	47	38	14	45	47	7·2	52
Right	Z. D.	35	45	35					47	1	6·0	36
„	„	35	45	0	35	47	5		48	55	4·1	17
Left	Alt.	64	10	50					51	30	1·5	2
„	„	64	11	0	35	47	8		54	37	1·6	3
Right	Z. D.	35	45	15					56	22	3·4	12
„	„	35	45	30	35	47	25		57	43	4·7	22
Left	Alt.	64	10	40					58	48	5·6	34
„	„	64	10	30	35	47	40	15	0	18	7·3	53
Right	Z. D.	35	45	50					2	10	9·2	85
	Mean				35	47	23				Mean ..	31·6
	Refraction ..					+	42					
	ζ_0 =				35	48	5				$31{\cdot}6 \times 2 = 63{\cdot}2.$	
	$-Am$ =					−	22					
	ζ =				35	47	43	$\phi = 38^\circ\ 58'\ 54''.$				

Data.

	H.	M.	S.
Æ of Star ..	14	51	14
Chron. Error	+	1	46
Chron. Time of Transit	14	53	0
	°	′	″
δ .. .. =	74	46	37
ζ_0 .. .. =	35	48	5
ϕ_0	38	58	32
log cos ϕ_0			9·8906
log cos δ			9·4192
log cosec ζ_0 ..			0·2330
log A			9·5429
log 63·2			1·8007
log Am			1·3436

For the above formula t should be less than 20 minutes, and ζ greater than 10°.

* The circle readings will be alternately altitudes and zenith distances ± the index error of the instrument, which error is eliminated in the mean of a pair of observations.

Longitude by Lunar Zenith Distances.

The local time and the chronometer error having been determined from the star observations

Let ζ_0 = the observed zenith distance of the moon's limb.
Θ = the local sidereal time of the observation of ζ_0.
L_1 = an assumed value of the longitude.
ΔL_1 = the required correction of L_1.
L = the true longitude = $L_1 + \Delta L_1$.
ϕ = the latitude.

Find the Greenwich time corresponding to Θ and L_1, for which take

δ = the moon's declination.
π = the moon's equatorial horizontal parallax.
S = the moon's geocentric semi-diameter.
} from the 'Naut. Alm.'

Let S_1 be the moon's apparent semi-diameter, and π_1 the corrected parallax.

$$\text{then } S_1 = S + \Delta S, \text{ and } \pi_1 = \pi + \Delta \pi;$$

and the values of Δ S and $\Delta \pi$ may be interpolated from the tables below, which are abridged from Chauvenet.

Also put $\delta_1 = \delta + e^2 \pi_1 \sin \phi \cos \delta$, in which $\log e^2 = 7{\cdot}8244$; and let r be the refraction for the apparent zen. dis. ζ_0;

$$\text{and let } \zeta_2 = \zeta_0 + r \underline{+} S_1,$$
$$\text{and } \zeta_1 = \zeta_2 - \pi_1 \overline{\sin} \zeta_2;$$

then the hour angle, t, is found from the equation

$$\sin^2 \tfrac{1}{2}t = \frac{\sin \frac{1}{2}[\zeta_1 + (\phi - \delta_1)] \sin \frac{1}{2}[\zeta_1 - (\phi - \delta_1)]}{\cos \phi \cos \delta_1},$$

after which the moon's right ascension, Æ, is found by the formula

$$Æ = \Theta - t.$$

The Greenwich mean time corresponding to the moon's Æ must be found from the 'Nautical Almanac'; with this and the local mean time a value of the longitude is determined, which, however, is approximate only, as t is computed with an approximate value of δ depending on the assumed

Values of Δ S, always +.							Values of Δ π, always +.			
Apparent Zen. Dis. of Moon.	Horizontal Semi-diameter.						Lati-tude.	Equatorial Parallax.		
	14′ 30″	15′ 0″	15′ 30″	16′ 0″	16′ 30″	17′ 0″		53′	57′	61′
°	″	″	″	″	″	″	°	″	″	″
0	13·7	14·6	15·6	16·7	17·7	18·8	0	0·0	0·0	0·0
10	13·5	14·4	15·4	16·4	17·5	18·6	10	0·3	0·3	0·4
20	12·9	13·8	14·7	15·7	16·7	17·7	20	1·2	1·3	1·4
30	11·8	12·7	13·5	14·4	15·4	16·3	30	2·7	2·9	3·1
40	10·5	11·2	12·0	12·8	13·6	14·4	40	4·4	4·7	5·1
50	8·8	9·4	10·1	10·7	11·4	12·1	50	6·2	6·7	7·2
60	6·9	7·3	7·9	8·4	8·9	9·5	60	8·0	8·6	9·2
70	4·7	5·1	5·4	5·8	6·1	6·5	70	9·4	10·1	10·8
80	2·4	2·6	2·8	3·0	3·2	3·4	80	10·3	11·1	11·9
90	0·1	0·1	0·1	0·1	0·2	0·2	90	10·6	11·4	12·2

longitude. Put L_2 for the approximate value of the longitude which is thus determined, and

put β = the increase of δ in a unit of time
and λ = „ Æ „ } at the Greenwich mean time of the observation of the moon;

$$\text{also let } a = \frac{\beta}{15\lambda}\left\{\frac{\tan\phi}{\sin t} - \frac{\tan\delta}{\tan t}\right\};$$

$$\text{then } \Delta L_1 = \frac{L_2 - L_1}{1 + a}, \text{ and } L = L_1 + \Delta L_1.$$

These formulæ are demonstrated in Chauvenet, vol. i. pages 383 to 385; and when several observations have to be reduced, they entail less labour of computation than any other formula.

Example.—In latitude $\phi = 38° \ 58' \ 53''$ and assumed longitude $L_1 =$ 5 h. 6 m. west of Greenwich, on May 2nd, 1849, the moon being east of the meridian, the zenith distance of the moon's upper limb was observed to be 57° 47′ 28·5″, when the local mean time was 5 h. 33 m. 21·6 s., and the local sidereal time Θ = 8 h. 16 m. 14·61 s.

Approximate Greenwich mean time, 10 h. 39 m. 21·6 s. for which we find from the 'Naut. Alm.'

$$\delta = +\,3^\circ\ 47'\ 47{\cdot}6''$$
$$S = 15\ \ 16{\cdot}4$$
$$\pi = 56\ \ 3{\cdot}1$$

and from the tables on page 22 we find

$$\Delta S = +\ 8{\cdot}1$$
$$\Delta S = +\ 4{\cdot}4$$
$$\left.\begin{matrix} e^2\pi_1 \sin\phi \\ \cos\delta \end{matrix}\right\} = +\ 14{\cdot}1$$

	°	′	″
$\zeta_0 =$	57	47	28·5
$r =$	+	1	30·9
$S_1 =$	+	15	24·5
$\zeta_2 =$	58	4	23·9
$-\pi_1 \sin \zeta_2 =$	−	47	38·1
$\zeta_1 =$	57	16	45·8
$\delta_1 =$	3	48	1·7

With these values of δ_1, ζ_1, and ϕ we find—

	H.	M.	S.
$t =$	−3	19	53·64;
but $\Theta =$	8	16	14·61;
whence the computed Æ $=$	11	36	8·25.

	H	M.	S.
The corresponding Greenwich mean time for this value of the Æ is	10	39	48·7
The local mean time is	5	33	21·6
Whence the approx. long. L_2 is	5	6	27·1

For the Greenwich mean time 10 H. 39 M. 48·7 S. $\begin{cases} \text{increase of Æ in 1 M.} = 2{\cdot}014\ \text{S.} = \lambda. \\ \quad ,,\quad \delta\ ,, \quad = 10{\cdot}01'' = \beta. \end{cases}$

Whence $a = -\,0{\cdot}3317$; and since $L_2 - L_1 = +\,27{\cdot}1$ s.,

$$\Delta L_1 = 40{\cdot}6\ \text{s.}, \text{ and } L = 5\ \text{H.}\ 6\ \text{M.}\ 40{\cdot}6\ \text{S.}$$

Formulæ for the reduction of Azimuth Observations.

(1.) When a star is observed at an elongation.

Let A be the azimuth, δ the declination, ϕ the latitude.

$$\text{Then } \sin A = \frac{\cos\delta}{\cos\phi}.$$

(2.) When a star is observed at a short distance from the elongation.

Let t be the hour angle at the time of elongation,

$$\text{then } \cos t = \frac{\tan \phi}{\tan \delta}.$$

Let $d\,t$ be the difference between the hour angles at the times of elongation and of observation, and dA the corresponding difference of azimuth.

$$\text{then } \tan dA = -2 \sin^2 \frac{d\,t}{2} \sec \phi \cot \delta \operatorname{cosec} t;$$

whence if $d\,t$ is expressed in *minutes of time*, and κ is a constant,

$$\log \kappa \text{ being } = \cdot 29303 + \log \sec \phi + \log \cot \delta + \log \operatorname{cosec} t,$$

$$dA'' = -\kappa\,(d\,t)^2.$$

(3.) When two stars are observed at their elongations.

Let their azimuths be A_1 and A_2, and their declinations δ_1 and δ_2,

$$\text{then } \sin A_1 = \frac{\cos \delta_1}{\cos \delta_2} \sin A_2.$$

The value of $A_1 + A_2$ or of $A_1 - A_2$ is given by the observations, $A_1 + A_2$ if the stars are at opposite elongations, $A_1 + A_2$ if they are at the same elongation. Suppose that we have

$$A_1 \pm A_2 = m,$$

$$\text{then } \cot A_1 = \cot m \pm \frac{\cos \delta_2}{\cos \delta_1} \operatorname{cosec} m,$$

$$\text{or } \cot A_2 = \cot m \pm \frac{\cos \delta_1}{\cos \delta_2} \operatorname{cosec} m.$$

Adjustments of the "Everest Theodolite, improved by Grover." (Furnished by Captain Pratt, R.E.)

It is stated that this theodolite is likely to be adopted into the service of the Royal Engineers. It is therefore thought advisable to describe its adjustments. The instrument is made by Cooke and Sons, York.

1. *Correction for Parallax.*—Adjust the eyepiece to distinct vision of cross hairs, and correct for parallax by means of the object-glass screw.

2. *Making the Level of the Horizontal Limb parallel to that Limb.*—Clamp the tribrach * to axis, and unclamp the horizontal vernier-plate. Move

* Modern instruments are set on a tribrach, or 3-armed support, at the top of the stand, instead of being screwed on to the top of it. This is a great improvement in many ways.

the latter so that the horizontal limb's level may be over, or parallel to, two foot-screws. By means of these screws bring the bubble to the centre of level. Turn the vernier-plate round 180°, and correct the level's error half by the foot-screws and half by the level's capstan-headed screws. Turn the vernier-plate back to its original position; and if the bubble is not now exactly in the centre, correct as before. Repeat the process till accuracy is obtained.

3. *Levelling the Instrument*, i. e., *making its vertical axis truly vertical.*—Clamp the tribrach to axis, and unclamp the horizontal vernier-plate. Level the horizontal limb's level by the foot-screws. Turn the horizontal vernier-plate round 90° and re-level. This will make the vertical axis approximately vertical. Then bring the bubble of the vertical limb's level to the centre of bulb by the two antagonising screws at bottom of vertical vernier-plate. Turn round 180°; and if the vertical limb's level is disturbed, correct half of the error by the foot-screws and half by the two antagonistic screws. Turn the horizontal plate 90°, and repeat the process till accuracy is obtained.

If the bubble of the level attached to the horizontal plate is now disturbed, bring it to centre of bulb by the capstan-headed screw, so as to make it an index of horizontality.

4. *Collimation.*

(a) *Vertical Collimation.*—Unclamp the vertical limb, and make its level horizontal by means of the antagonising screws. By means of the vertical limb's tangent-screw get the horizontal spider-line to cover some well-defined distant point. Read off the angle on the vertical verniers.

Reverse the instrument on its bearings, re-level, and re-intersect the same object. If now the vertical verniers read as at first, the vertical collimation is correct. If not, the mean of the readings is the true angular deviation from the horizontal. By means of the vertical limb's tangent-screw make the vertical verniers read this true deviation, and intersect the distant point by means of the antagonising screws.

This will disturb the level of the vertical limb. Restore its horizontality by means of the capstan-headed adjusting screws. The verniers should now read the same angle in both positions of the transit axis. If not, repeat the process till accuracy is obtained.

(b) *Horizontal Collimation.*—Intersect some well-defined distant point with the spider-lines. Reverse the instrument on its bearings. If there is any deviation from the intersection, correct half with the tangent-screw of the horizontal limb and half with the capstan-headed screws which move the diaphragm. Reverse the instrument on its bearings, and repeat similar corrections till accuracy is obtained.

METEOROLOGICAL HINTS TO TRAVELLERS. By R. STRACHAN (of the Meteorological Office).

Travellers may make useful meteorological observations for three distinct purposes: 1st, for contouring, or determining elevation above the sea; 2nd, for extending our knowledge of climate; 3rd, for aiding synoptic investigation; while for their own daily knowledge of the weather, they will be useful and interesting.

Whatever results may be deduced from the observations, the original register should be carefully preserved, to afford opportunity of investigating such anomalies as may at a future time call for inquiry. Every observation or set of observations necessarily requires a statement of the time and place. It is especially necessary to record the name of the place, or the position, that is, the latitude and longitude, where observations are made on the march. Observations intended to aid synoptic investigation must be made at some definite instant of Greenwich time. At present the Meteorological Bureau of the United States asks for observations made at 12h. 45m. P.M. Greenwich time.

Travellers while on the march may always keep a valuable meteorological note-book, but, when resident at any place for some time, a meteorological register, kept methodically, becomes more valuable. The hours of observing while on the march will be dependent on the times of encamping and decamping, or on the necessity for determining some height barometrically. In residence, the hours of observing should be at intervals of 12, 8, 6, or 4 hours, always dividing the twenty-four hours into equal parts, as 2, 3, 4, or 6; thus, 4 A.M., 8, noon, 4 P.M., 8, and midnight, are the most advisable hours, local time, for observing.

The meteorological instruments which a traveller will chiefly use are barometers and thermometers. Whether a barometer or its substitute, an aneroid, be used for contouring purposes, the same can be set up and registered in residence. It is advisable to keep all instruments in the shade, but it is especially necessary to do so with thermometers intended to show the temperature of the air, nevertheless they must be exposed to the free movement of the air. Inside a tent, a hut, or a verandah, they will commonly be too much sheltered. On the march, or whenever good shade cannot be had, it will be found a good plan to attach a string to the top of a pocket thermometer, and whirl the instrument round at arm's length for about half a minute. By this method even in full sunshine a very close approximation to the true temperature of the air may be had.

Every instrument used ought to be compared with a standard and tested thoroughly, both before commencing and after completing the journey. This can be effectually done at the Kew Observatory. Instrumental corrections should be carefully recorded in the register.

A rain-gauge consists of a funnel, a collector, and a glass measure. The funnel should have a deep circular aperture for the reception of the rain not less than 8 inches in diameter. All smaller sizes are wanting in accuracy, nevertheless they will be preferred for portability, and if so, care should be taken that they are really made to the size intended.

A small anemometer, or wind-gauge, by Lowndes, which fits into a small cubic box, about 4 or 5 inches in each dimension, will be found the best adapted for the requirements of travellers.

Artificial shade may be made for the thermometers, maximum, minimum, dry-bulb, and wet-bulb, when in residence, by means of a louvre-work box, about 18 to 24 inches in height, width, and depth. It must be roofed at top to keep off sunshine and rain, and have sides like Venetian blinds, through which the air may pass with freedom. It should be erected 4 feet above the ground, on wooden supports. The bottom of the cage should be full of perforations, but not entirely open to radiation from the ground beneath it. The thermometer should be disposed about the middle of the cage.

The observer should be careful to make it quite clear whether the directions of the wind, and bearings generally, are by compass, or referred to the astronomical north, south, east, and west. The wind's force and the weather should be noted according to the Beaufort system of notation, as given in most modern works on meteorology.

Photography. By the Rev. H. B. George, Fellow of New College, Oxford, first Editor of the 'Alpine Journal.'

All readers of these notes may be assumed to understand the mere outlines of the photographic process; that a glass-plate is covered with a chemical preparation sensitive to light, is exposed so many minutes or seconds in front of the picture which is to be taken, and is subsequently developed, or subjected to other chemical operations which serve to fix the picture on the plate; after which, impressions are taken from it by a process analogous to printing. By the ordinary methods, all this must be done before the plate has had time to dry, that is to say, within a few minutes: and inasmuch as the plate must be prepared and developed in the dark, it is impossible to take photographs in this way in places to which a dark tent cannot be taken, or where there is an absence of water, which is required in abundance for developing. There is a very convenient and portable box, ingeniously contrived both for storing the necessary chemicals and for a developing tent; which, by one or two additions, might be made to serve for the entire process. It was devised by Colonel Stuart Wortley, and is to be procured of Messrs. Chambers and Co., 251, Goswell Road. But even this is more than a traveller would carry far, and it in no way dispenses with the need of water. Moreover, much practice and skill in manipulation is required in order to prepare photographic plates successfully, and this few travellers possess or can be expected to acquire.

The discovery, however, of a method of preparing plates so that they can be used dry, that is to say, some time after preparation, and developed some time after exposure (always provided that until after development they are carefully secured from the light), has rendered it possible to take photographs anywhere and everywhere. The results obtained are not on the whole so satisfactory as with wet plates, but they are well worth having in themselves; and dry plates can be used in countless places where it would be impossible to prepare plates by any wet process. Moreover, all knowledge absolutely necessary for the use of them can be acquired in an hour.

Dry plates are now prepared in various ways, and by different makers, and doubtless there is still room for improvement in uniformity of production, especially in respect to the thickness of the glass, and possibly also in sensitiveness. Still, on the whole, the dry plates procurable are very fairly trustworthy: the chances are largely in favour of obtaining each time, if not a perfect picture, yet something of real value to the traveller. It is necessary to obtain information from the makers as to the sensitiveness of each kind of plate, which varies considerably, but one or two remarks may be useful. First, the more sensitive to light a plate is, the more it loses by keeping, so far as the writer's experience goes; a plate which would require a very short exposure when fresh, may want double the time a year later. Secondly, the more sensitive it is, the more care is required in keeping off the light: for instance, the plates of the Liverpool Dry Plate Company, which are not very sensitive, can be taken out without detriment in candle-light, or even moon-light, if not allowed to fall full on the plate; while it is scarcely possible to avoid injuring Colonel Stuart Wortley's Uranium plates (sold by Chambers and Co.), which are highly sensitive, unless the light is completely screened off by orange glass. This makes such a serious difference in travelling, that the writer is inclined to prefer the less-sensitive plates, as likely in the long run to give a larger proportion of successful pictures. Subject to these observations, it may be said that dry plates, with proper care, will keep as long as can be wanted. Dr. Kirk took some prepared plates with him to Africa in 1858, when the art of making them was in its infancy, which continued sensitive for more than five years and a half. The present writer happened to mislay a couple of plates after using them, and they furnished good pictures when developed nearly three years afterwards. Thus a traveller can not only take out prepared plates with him, but he can also bring them home for development. But anyone starting on a long journey will do well to learn how to develop his own plates (an easy thing enough), and carry with him the necessary apparatus, which weighs very little.* Thus he will be able to see how he has succeeded, and correct the times of exposure accordingly; besides, the plates, when once developed, are safe from injury through accidental exposure to light. The plates are supplied in packets carefully closed, and it is well not to open them until near the time of use. If they cannot be stowed in a proper grooved plate-box after use, the handiest way of repacking them

* Messrs. Murray and Heath supply a box fitted up for this purpose, which costs 2l. 10s.

is to pass an india-rubber band round each end of every alternate plate: they can then be made up into parcels without injury.

An invention has recently been brought out by Mr. Len Warnecke, of 10, Linden Grove, Peckham Rye, which, if it bears the test of use, will be of immense value to travellers; but the present writer can only speak of it from hearing. Mr. Warnecke prepares a sensitive tissue, which is supplied ready for exposure either in blocks of a dozen sheets, which are detached successively like the paper of a blotting-pad, or in bands, which are wound on a pair of small rollers within the dark slide, worked on the principle of a panorama. The roller dark slide is readily adapted to any camera, and the rollers are fitted with an index, by which any error in winding the tissue is at once detected. When a band of tissue is exhausted, it is detached and a new one substituted. The advantage of saving weight and risk of breakage is obviously enormous; but this tissue does not possess a high degree of sensitiveness.

Inasmuch as pictures taken on very small plates can now be enlarged with great success, the bulk of plates which must be carried is too small to be any serious burden, glass of the average thickness used for small plates weighing at the rate of about 1 lb. per square foot. Still more important is the fact that the camera and its accompanying dark slides may also be small and light. The best apparatus procurable for the traveller's purpose is the Miniature apparatus made by Messrs. Murray and Heath, of 69, Jermyn Street. This consists of a rigid camera whose dimensions are 5 × 4 × 4 inches, and which gives a picture measuring 4 × 3 inches. The present writer has made much use of a still smaller camera, known as Edwards', a cube of 3½ inches giving a picture 2½ inches square, on which Messrs. Murray and Heath's is supposed to be an improvement; and they would, no doubt, make a camera of these dimensions now, if desired. It is perhaps a little doubtful which is the most useful size. Murray and Heath's apparatus packs more conveniently together, and the larger pictures are in themselves far more satisfactory than the smaller, assuming that the trouble and expense of enlarging is not incurred. On the other hand, it is possible to take stereoscopic pictures with Edwards' by carrying a little metal plate with a curved groove, and the smaller size of the dark slide renders it possible to obtain a larger number of pictures by carrying the same weight.

A rigid camera is infinitely better for rough work than any folding one, which becomes useless if a fold cuts or wears through: the focussing is done by means of a sliding adapter attached to the lens. The dark slide in which the plates are carried contains two plates back to back. It is a question how many of these it is worth while to carry, but on the average six pictures is as many as one usually wants to take in the course of a day. A bit of black velvet to cover the camera is the only other thing necessary during the day. The store-box of plates, out of which the slides are filled at night, and into which the used plates are returned, will of course remain with the baggage. Pedestrians who are apt to quit their heavy

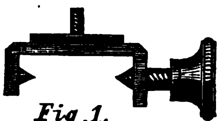
Fig. 1.


Fig. 2.

luggage for several days at a time will find it convenient to have a small box to hold a dozen or eighteen plates, which, with the dark slides, will furnish all they need for several days. The whole of this apparatus, exclusive of lenses and of a stand for the camera, will cost about *5l.* and weigh 4 or 5 lbs., and can be packed in a leather case measuring 8 × 7½ × 4½ inches.

It is difficult to express an opinion as to the best kind of lens, so much depends on the nature of the work to be done. Steinheil's probably is the most generally useful, if only one be taken; but so much is liable to be lost by using a lens which works slowly, while on the other hand pictures taken slowly are apt to give more accurate results, that there is much to be said in favour of taking two, one of which shall be as rapid in its working as possible. No better advice can be given here, in view of the varying requirements of the traveller, than that he should consult Mr. Murray, explaining the special ends he has in view. The price of lenses varies from about 1½ to 4 guineas.

The stand is of very great importance, especially to the pedestrian, and various plans may be adopted according to the nature of the expedition. One rule, however, holds good in all cases: do not have the camera to screw directly to the stand, but let it screw on to a saddle-shaped clamp (shown in section in fig. 1), to fit across the head of the stand (as in fig. 2), and secured there by a set screw. The little clamp takes up no appreciable space, and the risk of the screw being injured on a journey is removed. The stand may be an ordinary wooden tripod, which serves as a rather cumbrous walking-pole; Messrs. Murray and Heath make also a convenient folding one; a better thing still is a small tripod, which fits round and serves to steady a pole with a flat head, over which the clamp goes. Such a tripod may be used alone when convenient, and is very handy on mountain tops, &c., where the height of the camera above the ground does not signify. The writer has carried such a tripod on an ice-axe, and finds that it interferes scarcely at all with the facility of using the axe, except for continuous step-cutting. It might be adapted to any pole carried for other purposes, provided only the pole can have a flat head, or the clamp is altered accordingly.

The worst enemy of the dry-plate photographer is dust. He should not only keep his camera most carefully clean, wiping the lenses very frequently, but also gently brush the plates over with a camel's-hair pencil whenever they are moved into the dark slides and back into the store-boxes. The boxes should be fastened up very carefully, both to exclude light and dust, and also to prevent their being opened by servants or through any inadvertency. It is, of course, necessary to keep a register of the views taken, and the best mode of doing this is by marking on each plate a number corresponding to that in the traveller's journal; this can easily be done by scratching the corner of the collodion film. The dark slides should be numbered also for convenience of reference. The record of views taken ought to note, besides the date and subject, the hour, length of exposure, and state of weather.

The rules for determining the right length of exposure are simple in outline, but cannot be reduced to a formula. The operator must decide on the exact time required in each case by his own instinct; but the general principle is, that the greater amount of light received on the lens the more rapidly will the picture be printed; that is to say, a distant view requires less time than a near object, and an object bright in itself or brightly illuminated less than a dark object. Moreover, the amount of light diminishes in proportion to the distance from midday, and to the amount of cloud in the sky. As a rule, the morning is better than the afternoon; it seems also that as one goes higher the time of exposure tends to diminish. When in doubt it is well to expose a little more: for if a plate is under-exposed, the picture is not there; if it is over-exposed, the picture is there, though more or less burnt, and a little management in developing will correct much of this. There is no avoiding the ever-present difficulty that near and far objects, foreground and background, require, for perfection, different exposures. All we can do is to assimilate them as nearly as possible. If there is a great distance to be taken, choose a brightly-illuminated foreground: on a mountain top, for instance, prefer snow to rocks. Disturb the snow a little, if possible, to break its uniform surface; but rocks will not print themselves distinctly till the distance is spoiled. Similarly, it is impossible to obtain a satisfactory photograph of what is to the eye most attractive—a distant view framed in the branches of some closely-overhanging tree; one must be sacrificed to the other. As above stated, the time of exposure depends on the plates, and also on the lens used; but the range is very wide. A view taken under the most rapid conditions, as, for instance, from the top of Mont Blanc on a bright day, will take perhaps one-fifth of the time requisite for a dark object near at hand.

The outfit for an explorer should be:—

Camera with one or two lenses.

Extra lenses should be taken for safety on long expeditions.

At least 4 dark slides. (See that they all work easily in the camera, and keep them as much sheltered from the sun as possible to prevent their warping. It is desirable to keep them wrapped up in black or yellow cloth or oil-silk.)

1 small store-box, as above.

Larger store-boxes, as many as may be required.

Stand, according to circumstances.

2 or 3 clamps to fix camera on stand.

Plate for taking stereoscopic views, if the camera will admit of such being taken.

Some black velvet or cloth, and plenty of india-rubber bands for holding the velvet over the camera.

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*Surveys, with Sextant and Prismatic Compass.** By Major C. W. Wilson, R.E.

A traveller who intends to devote a portion of his time to the survey of the country he is about to visit, should consider before leaving home what he is going to do, and how he will do it. The character of the proposed survey, the projection to which it is to be referred, the scale or scales to be adopted, the instruments to be used, should be carefully thought over before commencing work, and there should be no hesitation when once upon the ground. A decision on these points depends on various considerations—such as the time and means at the disposal of the traveller, the object in view, the nature and geographical position of the country, &c.; and the following notes are confined to a few hints which may be useful in the field.

Projection.—When the extent of country to be laid down is small, it may be treated as a plane-surface, but when it is considerable, allowance must be made for curvature, and some projection of the sphere, or a portion of the sphere, adopted. The projection should be selected with reference to the latitude and local peculiarities of the country to be surveyed; the sheets should be prepared before leaving home by a competent draughtsman, and two or more copies of each taken, packed in a round tin plan-case. It may happen, however, that a projection has to be made in the field, and a few notes are given on the construction of Mercator's, the Conical, and the Rectangular Tangential Projections. In *Mercator's Projection* the true proportions are preserved between the meridians and the parallels, and the figures of the objects delineated are

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* It will be understood, that if a small theodolite can be carried, the work of surveying will be greatly facilitated.

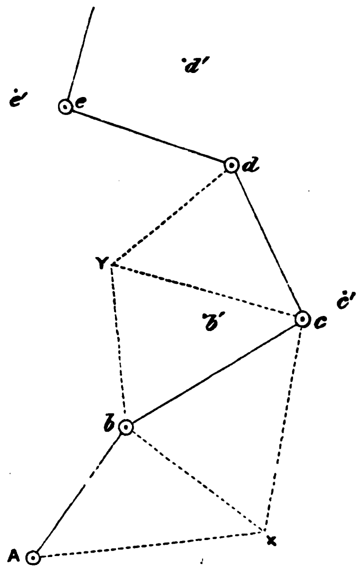
in every part correct; but the exaggeration at a distance from the Equator is so great that, beyond 50° or 60° a circular or polar projection is preferable. The advantage of Mercator's projection is, that the bearing and distance of one place from another, as measured on the map, is the same as on the globe itself; the traveller can thus lay down his route upon it with great readiness. The *Conical Projection* is well adapted for the representation of small portions of the sphere: but if the map is extended much above or below the middle latitude, the distant parts will be greatly distorted. The *Rectangular Tangential Projection* is well suited for maps on a scale of 10 miles to an inch; and the tables published by the late Sir Henry James provide the means of readily constructing the sheets required.

Scale.—For the fair plan, a scale of 10 miles to an inch is recommended; for the field-sketch or outdoor-work, a scale of 2 miles to the inch; or, if much detail is required, of one mile to the inch. The scale of 2 miles to the inch has this advantage—that the ordinary sketching-card 12″ × 15″ will contain sufficient ground—24 miles × 30 miles—for the day's work, and most of the points to which bearings are taken.

The classes of *Survey* to which attention may be directed are—1. A simple route-survey; 2. A district-survey; 3. A special survey of a small tract of country; and 4. A survey of a plot of ground containing ruins, &c. The only instruments supposed to be available are—sextant, watch or chronometer, prismatic compass, measuring tape, aneroid, &c.

1. *Route Survey.*—Arrived on the ground, the traveller must first fix, with as much accuracy as possible, the position of some point on the earth's surface to which his work may be referred. If he starts from the coast-line, the position of some well-defined point can generally be obtained from the Admiralty Charts, but if no such resource is available, the position of his initial point must be determined by astronomical observations. The latitude can be obtained by a good observer with a 6″ sextant to about 100 yards on the earth's surface; but the longitude cannot be found by lunar distances to within ten minutes (10 miles on the Equator). The position of the initial point, A, having been determined, work commences. The true bearing of some well-defined distant peak, or other landmark, is obtained, and this having been made "zero," a round of angles is taken with the sextant to conspicuous objects, some of which should be in the direction of the proposed line of march, and, if

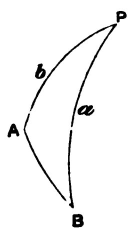
possible, near the first halting-place. Several observations of the zero-point are made with the compass, the needle being deflected each time, to obtain the variation, and the aneroid read for altitude. All angles should be booked at once in ink, and the names of the observed objects carefully noted; a rough outline-sketch of the peaks or other landmarks will be found useful in identifying points as the work proceeds. The initial point, A, is pricked off on the sketching-card in a suitable position for



laying down the day's march, and surrounded by a circle ⊙; the observed angles are plotted; and a magnetic meridian is drawn; all is then ready for plotting the route. The compass is set up at A, and the sights of the instrument are directed on some object, *b′*, in the direction of the line of march; the bearing of *b′* is read off and plotted from A on the field-sheet by means of the protractor; bearings are then taken to conspicuous objects such as X, which appear to lie near the line of march, and these are likewise plotted. The march now commences in the direction Ab', and is continued to the point b' where the route is found to turn to the right; the distance Ab, measured during the march, is laid down upon the field-sheet, and the point b, surrounded by a circle ⊙; the compass is then set up at b, and the bearing of an object, c', in the direction of the new line of march, read off and plotted from b on the field-sheet; bearings are also taken to objects, such as X, Y, on either side of the route, and plotted; the point X having also been observed from A, is now fixed. The march is again taken up in the direction $b\ c'$ until a point c is reached, at which the road bends to the left, the distance $b\ c$ laid down, and so on until camp B is reached. At B, observations should be made in the evening for time and latitude; and in the morning, observations similar to those which have been made at A. Should the camp be near one of the points observed to from A, the distance and true bearing of such point from B should be determined, with a view of fixing its position. At certain camps the longitude should be found by lunar distances, to serve as a check on the traverse-survey. Distances on the line of march may be measured by counting or timing the paces of a man, or by counting or timing the paces of a horse, mule, camel, &c., whose length of step is known. Time-measurement will be found most convenient, and, with care, will give very good results. Compass-bearings need only be taken at every second station on the line of march. Objects on either hand should, where possible, be fixed by three bearings. It is not desirable to take compass-bearings to points more than 6 or 7 miles distant, as the prismatic compass can seldom be depended upon to within one degree, and an error of this amount in 6 or 7 miles would give an error of ·05 inch on a scale of 2 miles to the inch. If the route runs near a peak, of which the true bearing has been determined from A, it should be ascended, and a round of angles taken with the sextant, making A the zero-point. When there is a mid-day halt, the meridian altitude of the sun should be observed. If a field-sketch cannot be kept up, the route should be entered in a field-book, and afterwards plotted, before details are forgotten. A book—with every alternate page ruled into squares by strong lines, and subdivided by finer lines, the smaller squares representing five minute intervals of time, the larger ones one hour—will be found of great use in making a rough sketch of the route, or a modification of the form used in booking a traverse-survey may be adopted; in all cases the bearings, distances, &c., should be clearly written in the book.

In this field-sketch the ground has been treated as a plane surface, and as soon as convenient the work should be transferred to the projection on the fair plan. In doing this it becomes necessary to calculate the latitudes and longitudes of the camps, and other points, from the material provided by the survey; when this has been done, the fixed points are laid down in their true position on the map, and the detail reduced to the proper scale.

2. *District Survey.*—The basis of any survey of an extensive district should be a system of triangulation, and the first step is the measurement of a base line. With no instruments except a sextant, tape, and prismatic compass, the best plan is to measure an astronomical base, and thence extend the triangulation as far as may be necessary. Two suitable points, A and B, lying nearly north and south of each other, are selected as the ends of the proposed base; the position of A on the earth's surface is determined at the point itself, the true bearing of B from A is obtained, and B having been made zero, a round of angles is taken from the sextant



to conspicuous points; camp is then moved to the vicinity of B, and observations for latitude made at that point; the true bearing of A from B is then obtained, and a round of angles taken to the points previously observed to from A. The length of the base AB can then be computed, and the position of several of the points observed to from A and B determined. The fixed points are next laid down on the field-sheet, and the detail filled in with the prismatic compass. In this way the triangulation may be extended over the district to be surveyed, care being taken to check the work occasionally by observations for latitude at selected points.

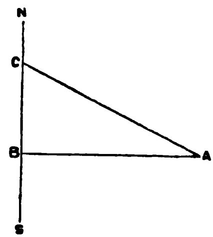
The following notes and problems* will be found useful in constructing the map :—

Problem I.—Let A and B be two stations visible from one another, $AP = b$, $BP = a$, their observed co-latitudes, the angles A and B their reciprocal true azimuths, and APB, or P, the required angular difference of longtide. Then by spherical trigonometry—

$$\text{Cot.}\ \tfrac{1}{2}\,P = \frac{\cos.\ \frac{1}{2}\,(a+b)}{\cos.\ \frac{1}{2}\,(a-b)}\ \tan.\ \tfrac{1}{2}\,(A+B)$$

which determines P.

Problem II.—The latitude and longitude of any point being known, that of any other point within a short distance can be determined by plane trigonometry. Suppose the latitude and longitude of the camp at A to be

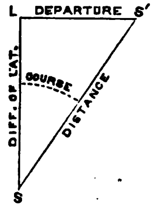


known, whence that of a neighbouring peak or land-mark, C, is to be determined; the distance AC must be measured, and the azimuth NCA observed, then the difference of longitude AB is the sine of ACB to radius AC, and the difference of latitude BC is the co-sine to the same angle and radius.

Problem III.—The distances between two places are generally resolved by plane trigonometry, the difference of latitude SL, and the azimuth S′SL, called the *course*, forming a right-angled triangle, in which SS′, the

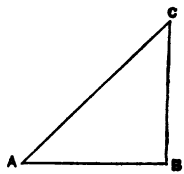
* Problems II.–V. are taken from Frome's 'Outline of a Trigonometrical Survey,' revised by F. Capt. Warren, R.E.

distance, is determined; the other side LS′, termed the *departure,* being the sum of all the meridional distances passed over.



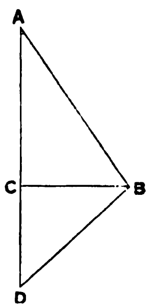
Problem IV.—Given the distance travelled on a given parallel of latitude to find the difference of longitude.

Again, in the triangle ABC, let AB represent the distance or departure,



and the angle BAC be equal to the latitude, then AC, the hypothenuse, will be equal to the difference in the longitude.

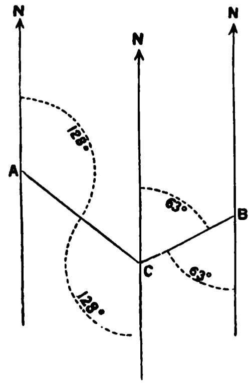
Problem V.—Given the departure to find the difference of longitude.



Also, if DB represent the distance, and CD the difference of latitude, then BCD will be a right angle, and BC the departure, nearly equal to the meridian distance in the middle latitude. If, then, in the triangle ABC the angle ABC be measured by that middle latitude, AB, the hypothenuse will be nearly equal to the difference of longitude between D and B.

For the variation of the compass, it is convenient to take a bearing of the sun at sunset or sunrise; or, if this cannot be done, an azimuth of the sun at any time three hours before or after noon will answer equally well. The angular distance between the sun, when its own diameter is above the horizon, and any well-defined peak, measured with the sextant, gives the true bearing.

To find the sun's true amplitude for any day:—to the log-secant of the



latitude, rejecting the index, add the log-sine of the sun's declination corrected for the time and place of observation. Their sum will be the log-sine of the true amplitude. If the true and magnetic amplitudes be both north or both south, their difference is the variation; but if one be north and the other south, their sum is the variation; and to know whether it be easterly or westerly, suppose the observer looking towards that point of the compass representing the magnetic amplitude; then, if the true amplitude be to the right hand of the magnetic, the variation is east, but if to the left hand, it is west.

In filling in a survey, the observer can fix his position, C, by observing two fixed points, A and B, and plotting from those points the opposite bearings to those observed, their intersection fixes the point required. The nearer the two bearings meet at a right angle the more correct will the point be determined, and, if a third fixed point is visible, a bearing to it will act as a check on the other.

A third and accurate method of fixing the position is by the angles subtended between three known objects. The instrument called the station-pointer is generally used for this purpose; but the position may also be found with a pair of compasses and a protractor, or, more simply, as follows, by means of a protractor and a sheet of tracing paper. Draw a line through the centre of the paper; place the protractor on it near to the bottom of the sheet; lay off the right-hand angle to the right, and the left-hand angle to the left of the centre line; rule pencil-lines, radiating from the point over which the centre of the protractor has been placed, to the points that has been laid off; then place the paper on the plan or map, and move it about until the three lines coincide with the objects taken; prick through the points that lay beneath the centre of the protractor, and the observer's position is transferred to the plan. When possible, the centre object should be the nearest.

Any object whose true bearing is east or west must be in the same latitude as the place of the observer.

Any object whose true bearing is north or south must be in the same longitude as the observer.

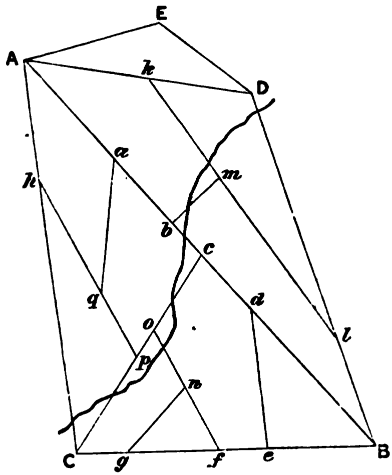
3. *Special survey of a small tract of country*, with compass and tape only.—First walk over the ground and examine it, with a view to the selection of prominent points for stations, and of a level space for the measurement of a base. Having fixed upon a base, AB, set the compass up at A and take a round of bearings to B and other selected stations, C, D, E, &c.; then mark A on the field-sheet, in such a position as will enable the whole sketch to go on the sheet, and protract the several bearings from it. Mark A on the ground with a pile of stones or staff, measure the base A B with the tape or by pacing, lay the distance down on the field-sheet to the adopted scale, set the compass up at B and take a round of bearings to A, C, D, E, &c. These bearings are now plotted and their intersections with the bearings from A fix C, D, E, &c.; in this manner a rough triangulation is established and a number of points fixed, by the aid of which the detail can be filled in.

The paper, or field-sheet, for sketching with a prismatic compass should have parallel lines at unequal distances ruled upon it, to be considered as east and west lines.

4. *Survey of a plot of ground containing ruins, &c.*—In making a survey with a tape alone we are confined to the simplest geometrical figure—the triangle, as it is the only one of which the form cannot be altered, if the sides remain constant. In carrying out such a survey, divide the surface into a series of imaginary triangles as large as the nature of the ground will admit of, and attend to the following rules:—

1. Do not be in a hurry to commence work, but walk over the ground and make a rough eye-sketch of it on paper.

2. Select two points, as far apart as possible, visible from each other



A B —Main line.
A B C } —Principal triangles.
A B D }
C C —Tie line.

and commanding a good view; let the points be near the boundaries of the ground, and so situated that the line joining them forms a sort of diagonal; this becomes the *main* line.

3. Select a point on each side of the main line, near the boundary of

the work, to which lines can be measured from each end of it, thus giving two large triangles; then measure a check, or *tie* line, from one of the verticles to a point at or near the middle of the opposite side.

4. On the sides of these triangles erect smaller ones to embrace all the ground to be surveyed.

5. Measure lines from any station laid down, or from any part of a line connecting two of them in directions most convenient for obtaining the detail, taking offsets to such objects as present themselves.

The interiors of large buildings should be measured in a somewhat similar way by dividing them into imaginary triangles and measuring tie lines.

The great principle in all surveys is to work from a whole to the parts, errors are thus subdivided and time and labour economised.

The following symbols are recommended for adoption :—

∠'s signifies angles.
▲ a station in the triangulation.
⊖ „ fixed by latitude.
⦶ „ „ longitude.
⊕ „ „ lat. and long.
⊙ „ „ true bearing.
R. t. „ „ right tangent.
L. t. „ „ left „

To Construct a Map on Mercator's Projection.

On a sheet of cartridge paper, 13 inches by 20, it is proposed to construct a map on Mercator's projection, on a scale of 10 miles to an inch equatorial—*i.e.* 6 inches to the degree of longitude.

Limits of the Map { Lat. 31° to 33° N.
Long. 34° to 36° E.

Draw a base line, find its centre, and erect a perpendicular to the top of the paper; the extremes of longitude 34° and 36° added together and divided by 2, give 35° the central meridian, and which is represented by the perpendicular; on each side of it lay off 6 inches, and erect perpendiculars for the meridians 34 and 36; divide the base line into 10-mile divisions, and the part from 35° 50′ to 36° 00′ into miles for the latitude scale.

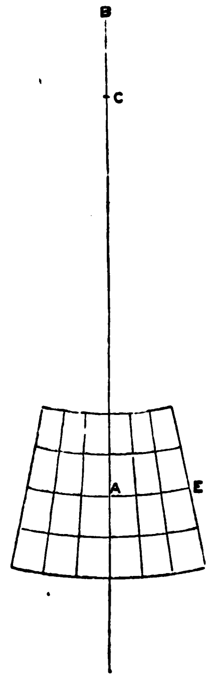
From Table A, take the following quantities :—

Lat. 31° to 32° = 1° 10′·4 = the distance between parallels 31° and 32°

„ 32° to 33° = 1° 11′·1 „ „ „ 32° „ 33°

2° 21′·5 „ „ „ 31° „ 33°

Having thus obtained the distances between the required parallels, divide the map into squares of 10 miles each way, and the map is ready for the projection of the route.



The conical projection or development is carried out thus: draw a straight line, A, B, to represent the central meridian of the intended map,

(A.)—Table to construct Maps on Mercator's Projections.

	0	1°	2°	3°	4°	5°	6°	7°	8°	9°
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0		1 00	1 00·1	1 00·1	1 00·1	1 00·2	1 00·3	1 00·4	1 00·5	1 00·6
10	1 00·9	1 01	1 01·2	1 01·5	1 00·7	1 02	1 02·2	1 02·6	1 02·9	1 03·3
20	1 03·6	1 04·1	1 04·5	1 04·9	1 05·5	1 05·9	1 06·5	1 07	1 07·7	1 08·2
30	1 09	1 09·6	1 10·4	1 11·1	1 12	1 12·8	1 13·7	1 14·6	1 15·7	1 16
40	1 17·6	1 10	1 20·1	1 21·4	1 22·7	1 24·2	1 25·6	1 27·1	1 28·8	1 30·6
50	1 32·4	1 34·3	1 36·4	1 38·6	1 40·8	1 43·4	1 45·9	1 49	1 51·4	1 54·8
60	1 58·3	2 01·8	2 05·8	2 09·9	2 14·5	2 19.14	2 24·7	2 30·5	2 36·8	2 43·8
70	2 51·3	2 59·8	3 09·1	3 19·6	3 31·3	3 44·6	3 59·8	4 17·1	4 37·4	5 01·1
80	5 29·5	6 03	6 46·4	7 40.3	8 51·1	10 27·7	12 47·9	16 29·6	23 4·3	39 42.2

Use of the Table.

Find in the Table the required parallel: the tens at the side, and the units at the top. At their intersection will be found, in degrees and minutes, the distance of the required parallel from the next less degree; to be measured from the scale of longitude on the map in progress.

Given the parallel of 30°—required that of 31°.

30 at the side, and 1 at the top, intersects at 1° 09′·6, the required distance of the two parallels.

Given the parallel of 31°—required that of 33°.

32° = 1° 10·4
33° = 1° 11′·1

2° 21′·5 the distance between the 31° and 33° parallel.

(B.)—Given the Departure, to find the Difference of Longitude.

	0	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°		1·0001	1·0006	1·0013	1·0026	1·0038	1·0055	1·0075	1·0098	1·0125
10	1·0154	1·0187	1·0224	1·0261	1·0306	1·0353	1·0403	1·0457	1·0514	1·0578
20	1·0642	1·0711	1·0785	1·0864	1·0946	1·1034	1·1126	1·1224	1·1326	1·1434
30	1·1547	1·1666	1 1792	1·1924	1·2062	1·2208	1·2361	1·2521	1·2690	1·2868
40	1·3054	1·3250	1·3456	1·3673	1·3902	1·4142	1·4395	1·4663	1 4945	1·5242
50	1·5557	1·5890	1·6242	1·6616	1·7013	1·7435	1·7883	1·8361	1·8871	1·9416
60	2·0000	2·0626	2·1301	2·2027	2·2812	2·3662	2·4586	2·5593	2·6695	2·7904
70	2·9238	3·0716	3·2361	3·4204	3·6280	3·8637	4·1337	4·4454	4·8097	5·2406
80	5·7587	6·3925	7·1856	8·2057	9·5664	11·475	14·334	19·108	28·653	57·307

Use of the Table.

Find in the Table the required parallel, the tens at the side and the units at the top: at their intersection will be found a quantity which, multiplied by the departure, gives the "diff. of longitude."

The departure from the meridian on the parallel of 34° was 25 miles—required the diff. of longitude.

$$25' \times 1·20 = 30'·co \text{ the diff. of longitude.}$$

In the parallel of 60° the departure was 30 miles.

$$30' \times 2 = 60 \text{ miles, or 1 degree.}$$

In the parallel of 35°N. the route was N. 40 W., 37 miles' distance.

By Traverse Table, 40° course, 37 (Dis.) = 23·8 (Dep.) × 1·22 = 29·03 (Miles), diff. of longitude.

and after having decided on the scale on which it is to be laid down, set off along this line A B from the point A scales of equal parts, for each 1° or 5°, as the size of the scale may admit. Also measure off from A towards B the distance AC = 57·29578 × length of 1° in inches × cot. lat. of A. Then with C as a centre and C A as a radius, describe an arc of a circle through the point A, representing the parallel of middle latitude, and divide it also into equal parts indicating 1° or 5° of longitude, each 1° of longitude being equal to 1° of lat. × cos. lat. of A; and from C draw the radiating lines, representing the meridians through the points laid off on A E, and also concentric circles through the points marked off on A B for each 1° or 5° for the parallels of latitude.

For the Rectangular Tangential Projection, see a pamphlet with Tables published by the Ordnance Survey Department, "On the construction and use of marginal sheet lines, for the uniform projection of maps in any part of the world."

Table for Rough Triangulation without the usual Instruments and without Calculation. By Francis Galton, F.R.S.

A traveller may ascertain the breadth of a river, or that of a valley, or the distance of any object on either side of his line of march, by taking about 60 additional paces and by making a single reference to the Table on the following page.

Suppose he is travelling from A to Z (Fig. I., p. 68), and wishes to learn the distance from A to C; and, it may be, also the angle A. Let him as follows (referring now to Fig. II.).

1. Leave a mark at A. 2. Walk 10 paces towards Z, and make a mark, calling the place *m*. 3. Walk back to A. 4. Walk 10 paces towards C. 5. Walk to *m*, counting the paces to the nearest half-pace. (This gives the measurement of the line *a* (Fig. I.), which is the chord of the angle A, to radius 10.) 6. Walk 80 paces towards Z; make a mark, calling the place *n*. 7. Walk 10 paces towards Z, calling the place B; this completes 100 paces from A. 8. Walk 10 paces towards C. 9. Walk to *n*, counting the paces to the nearest half-pace. (This gives the line *b*, which is the chord of the angle B, to radius 10.)

Now enter the Table with *a* at the side and *b* at the top, and read off the distance A C, and the Angle A if also required.

TABLE for Rough Triangulation without the usual Instruments and without Calculation. By FRANCIS GALTON, F.R.S.

	Angle °	Angle ′	5 o	5 ½	6 o	6 ½	7 o	7 ½	8 o	8 ½	9 o	9 ½	10 o	10 ½	11 o	11 ½	12 o	12 ½	13 o	13 ½	14 o	14 ½
5 o	28	58	57	60	64	67	70	73	75	78	81	84	87	89	92	95	98	101	105	109	113	118
5 ½	31	56	55	59	62	65	69	72	74	78	81	84	87	90	93	96	100	103	107	112	116	122
6 o	34	56	54	57	61	64	68	71	74	77	80	84	87	90	94	97	101	105	110	115	120	126
6 ½	37	56	53	56	60	63	67	70	74	77	80	84	87	91	95	99	103	108	113	119	125	132
7 o	41	0	52	55	59	63	66	70	73	77	81	85	88	92	96	101	106	111	117	123	130	139
7 ½	44	4	51	55	58	62	66	70	73	77	81	85	89	94	98	103	109	114	121	128	136	146
8 o	47	10	50	54	58	62	66	70	74	78	82	86	91	95	101	106	112	118	126	134	144	156
8 ½	50	20	49	53	57	61	65	70	74	88	83	88	92	98	103	109	116	123	132	141	153	
9 o	53	30	49	53	57	61	66	70	75	79	84	89	94	100	106	113	121	129	139	150		
9 ½	56	4	49	53	57	62	66	71	76	81	86	91	97	103	110	118	126	136	147			
10 o	60	0	48	51	57	62	67	72	77	82	88	94	100	107	115	123	133	145				
10 ½	63	22	48	53	58	63	68	73	78	84	90	97	104	112	120	130	141	154				
11 o	66	44	49	53	58	64	69	74	80	86	93	100	108	117	127	138						
11 ½	70	12	49	54	59	65	70	76	83	89	97	105	113	124	135	147						
12 o	73	46	50	55	60	66	72	79	85	93	101	110	120	131								
12 ½	77	22	50	56	62	68	75	81	89	98	106	117	128	141								
13 o	81	6	52	57	64	70	77	85	93	103	113	125	138	155								
13 ½	84	56	53	59	66	73	81	90	99	109	121	135	150									
14 o	88	52	55	62	69	77	85	95	106	118	132	148										
14 ½	92	56	57	65	73	81	91	102	114	129	145											
15 o	97	10	60	68	77	87	99	110	126	143												
15 ½	101	36	64	73	83	95	108	123	141													
16 o	106	16	60	79	90	105	121	140														
16 ½	111	12	76	88	103	120	141															

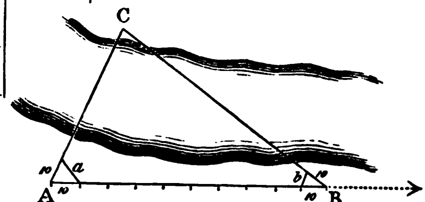


FIG. I.

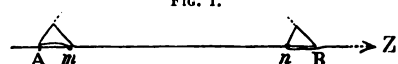


FIG. II.

To find A C and angle A:—Enter with *a* at the side and *b* at the top. To find B C and angle B:—Enter with *b* at the side and *a* at the top.

If the Table be entered with *b* at the side and *a* at the top, it gives B C (and B).

Of course the units need not be paces: feet, furlongs, miles, hours' journey, or anything else will do as well; and the units of A B need not be the same as those of *a* and *b*. Also any multiple or divisor of 100 for A B may be used, if the tabular number be similarly multiplied.

EXAMPLES.

a (in paces).	*b* (in paces).	A B.	A C.	Angle A.	B C.	Angle B.
				° ′		° ′
5	6½	100 paces	67 paces	28 58	53 paces	37 56
5	6½	50 miles	33½ miles	28 58	26½ miles	37 56
10½	7	100 paces	68 paces	63 22	92 paces	41 0
10½	7	1000 paces	680 paces	63 22	920 paces	41 0

Particular care must be taken to walk in a straight line from A to B. It will surprise most people, on looking back at their track, to see how curved it has been, and how far B *n* is from pointing truly towards A. It is important to sight some distant object in a line with Z when walking towards it.

The triangle A B C must be so contrived that none of its angles are less than 30°, or the chords of the angles at A and B will not be found in the Table. These cases cease to give reliable results when the measurements are rudely made, and have therefore been omitted.

Should a traveller have no Tables by him, he can always *protract* his measurements to a scale on a sheet of paper, or even on the ground, and so solve his problem. If real accuracy be aimed at, it is clear that it may be obtained by careful measurements of the base and chords, combined with a rigorous calculation, as was first suggested by Sir George Everest, formerly Surveyor-General of India. (See 'Journ. R. Geog. Soc.,' 1860, p. 122.)

MEASUREMENT OF THE NUMBER OF CUBIC FEET OF WATER CONVEYED BY A RIVER IN EACH SECOND.

The data required are—the area of the river section and the average velocity of the whole of the current. All that a traveller is likely to obtain, without special equipment, is the area of the river-section and the average velocity of the *surface* of the current, which is less than that of its entire body, owing to frictional retardation at the bottom.

To make the necessary measurements, choose a place where the river runs steadily in a straight and deep channel, and where a boat can be had. Prepare a few floats, of dry bushes with paper flags, and be assured they will act. Post an assistant on the river-bank, at a measured distance, of about half the estimated width of the river, down stream, in face of a well-marked object. Row across stream in a straight line, keeping two objects on a line in order to maintain your course. Sound at intervals from shore to shore, fixing your position on each occasion, by a sextant-angle between your starting-place and your assistant's station, and throw the floats overboard, signalling to your assistant when you do so, that he may note the interval that elapses before they severally arrive opposite to him. Take an angle from the opposite shore, to give the breadth of the river.

To make the calculation approximately, protract the section of the river on a paper ruled to scale in square feet, and count the number of squares in the area of the section. Multiply this by the number of feet between you and the assistant, and divide by the number of seconds that the floats occupied, on an average, in reaching him.

Important rivers should always be measured above and below their confluence; for it settles the question of their relative sizes, and throws great light on the rainfall over their respective basins. The sectional area at the time of highest water, as shown by marks on the banks, and the slope of the bed ought also to be ascertained.

EXAMPLE.

Distance from Shore	Starting-place.									Opposite Shore.	
Whence the boat started, measured in feet	0	90	160	240	330	420	500	600	700	780	
Depth at those distances measured in feet..	0	2	3½	4	4	5½	7	6½	3½	0	
Time required for float to drift opposite to assistant, measured in seconds	—	48	50	40	33	29	27	30	50	—	Average. 38·4

Distance of assistant, in feet, 150.

By protracting the data in the first two lines, on ruled paper as described above, it will be found that the area of the section is 3260 feet or thereabouts; this, multiplied into 150, gives 489,000 cubic feet of water as the contents of the river at any given moment between the line of soundings and the assistant. As this amount passes by in 38·4 seconds, the number of cubic feet per second is the former number divided by the latter, which gives 12,734.

It must be distinctly understood that this number is only roughly approximative, and that is excessive. However, with the above data, an engineer would be able to make a somewhat better calculation. In the meanwhile, the traveller might consider the flow of the river in question, to be between 10,000 and 13,000 feet per second.

Paper Squeezes of Inscriptions. By the Rev. F. W. Holland.

Some paper for "squeezes" should be taken, where inscriptions are likely to be met with. Many kinds of paper are suitable for this purpose, but that used by engravers is perhaps the best, since it combines a good substance and strength, with sufficient power of absorption. The process of taking squeezes is very simple. All dust or dirt should first be removed from the inscription with a rough brush. The paper should then be cut to the requisite size, and laid upon it. With a soft close-haired brush, like a hat-brush, water should now be sprinkled upon the paper, and when thoroughly wetted, the brush should be used to press it into every portion of the inscription, so that a perfect impression may be taken. The paper should be left upon the inscription until thoroughly dry, and may then be rolled up without fear of spoiling the "squeeze." When the paper is thin, several sheets may be added, with the use of paste or rice-water, until sufficient substance be obtained. I have in this way taken excellent squeezes with merely whitey-brown paper. A store of paper, a few brushes, and a pair of large scissors for cutting the paper, are all the materials that are required.

Hints to Travellers on the Collection of Objects of Natural History. By H. W. Bates, Assistant-Secretary, R.G.S.

Travellers who intend devoting themselves specially to Natural History will generally possess all the requisite information beforehand. It is to those whose objects or duties are of another nature, or who, whilst on a purely geographical land-exploration, wish to know the readiest means of collecting, preserving, and safely transmitting specimens they collect that the following hints are addressed:—

Outfit.—Double-barrel guns, with spare nipples, breech-loaders to be preferred; and a few common guns to lend to native hunters—especially if going to the interior of Tropical America.

Fine powder in canisters, and fine shot (Nos. 8 and 11), or cartridges, must be taken from England: coarse powder and shot can be had in any part. A good supply of the best caps.

Arsenical soap, a few pounds in tin cases; brushes of different sizes.*

Two or three scalpels, scissors (including a pair of short-bladed ones), forceps of different sizes for inserting cotton into the necks of birds' skins; needles and thread.

A few small traps, with which to capture small (mostly nocturnal) mammals.

Strong landing-net for water-mollusks, &c. Two stout insect *sweeping-nets.*

Cylindrical tin box for collecting plants, with shoulder-strap.

A few dozens of small and strong broad-mouthed bottles; and a couple of corked pocket-boxes.

Insect-pins; a few ounces of each Nos. 5, 14, and 11.

Stone jars for reptiles and fishes in spirit: to fit four in a box, with wooden partitions. If animals in spirits are to be collected largely, a supply of sheet-tin or zinc, with a pair of soldering-irons and a supply of soft solder, must be taken instead of stone jars. Cylindrical cases can then be made of any size required. By means of the soldering apparatus, also, empty powder-canisters and other tin vessels can be easily converted into receptacles for specimens.

A ream or two of botanical drying-paper, with boards of same size as the sheet, and leather straps.

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* Most of the articles of a Naturalist's outfit can be obtained, at a few days' notice, of Mr. E. T. Higgins, Natural History Agent, 22, Bloomsbury-street, W.C.

A few gross of chip pill-boxes in nests.

A dozen corked store-boxes (about 14 inches by 11 inches, and 2½ inches deep), fitted perpendicularly in a tin chest.

A few yards of india-rubber waterproof sheeting, as temporary covering to collections in wet weather, or in crossing rivers.

A set of carpenter's tools.

An outfit may be much lightened by having all the provisions and other consumable articles packed in square tin cases, and in boxes and jars of such forms as may render them available for containing specimens. If the traveller is going to the humid regions of the Indian Archipelago, South-eastern Asia or Tropical America, where excessive moisture, mildew, and ants are great enemies to the naturalist, he should add to his outfit two drying-cages; for everything that is not put at once into spirits is liable to be destroyed before it is dry enough to be stowed away in boxes. They may be made of light wood, so arranged as to take to pieces and put together again readily; one, for birds, should be about 2 feet 6 inches long by 1 foot 6 inches high and 1 foot broad; the other, for insects and other small specimens, may be about one-third less. They should have folding doors in front, having panels of perforated zinc, and the backs wholly of the latter material: the sides fitted with racks to hold six or eight plain shelves, which, in the smaller cage, should be covered with cork or any soft wood that may be obtained in tropical countries. A strong ring fixed in the top of the cage, with a cord having a hook attached at the end by which to hang it in an airy place, will keep the contained specimens out of harm's way until they are quite dry, when they may be stowed away in close-fitting boxes. If this plan be not adopted it will be almost impossible to preserve specimens in these countries.

Collecting.—The countries which are now the least known with regard to their Natural History, are New Guinea and the large islands to the east of it, Northern Australia, the interior of Borneo, Thibet, and other parts of Central Asia, Equatorial Africa, and the eastern side of the Andes, from east of Bogota to the south of Bolivia. A special interest attaches to the indigenous productions of Oceanic Islands, *i. e.* islands situated at a great distance from any large tract of land. Those who have opportunities would not fail of making interesting discoveries by collecting specimens of the smaller animals (insects, mollusks, &c.) and plants in these remote localities. The truly indigenous species will have to be sought for on hills or in the remote parts where they are more likely to have escaped extermination by settlers and the domestic animals introduced by them. In most of the better known countries the botany has been better investigated than the zoology, and in most countries there still remains much to be done in ascertaining the exact station, and the range, both vertical and horizontal, of known species. This leads us to one point which cannot be too strongly insisted on, namely, that some means should be adopted by the traveller to record the exact locality of the specimens he collects. In the larger dried animals this may be done by written tickets attached to the specimens; in pinned insects a letter or number may be fixed on the pins of all specimens taken at one place and time—the mark to refer to a note-book. The initial letter, or first two or three letters, of the locality is perhaps the readiest plan; and when all the specimens taken at one place can be put into a separate box one memorandum upon the box itself will be sufficient. Reptiles and fishes can have small parchment tickets attached to them before placing in spirits.

A traveller may be puzzled, in the midst of the profusion of animal and vegetable forms which he sees around him, to know what to secure and what to leave. Books can be of very little service to him on a journey, and he had better at once abandon all idea of encumbering himself with them. A few days' study at the principal museums before he starts on his voyage may teach him a great deal, and the cultivation of a habit of close observation and minute comparison of the specimens he obtains will teach him a great deal more. As a general rule, all species which he may meet with for the first time far in the interior should be preferred to those common near the civilised parts. He should strive to obtain as much variety as possible, and not fill his boxes and jars with quantities of specimens of one or a few species. But as some of the rarest and most interesting species have great resemblance to others which may be more common, he should avail himself of every opportunity of comparing the objects side by side. In most tropical countries the species found in open and semi-cultivated places are much less interesting than those inhabiting the interior of the forests, and it generally happens that the few handsome kinds which attract the attention of the natives are species well known in European museums. In botany a traveller, if obliged to restrict his collecting, might confine himself to those plants which are remarkable for their economical uses; always taking care to identify the flowers of the tree or shrub whose root, bark, leaves, wood, &c., are used by the natives, and preserving a few specimens of them. But if he is the first to ascend any high mountain, he should make as general a collection of the flowering plants as possible, at the higher elevations. The same may be said of insects found on mountains, where they occur in great diversity—on the shady and cold sides rather than on the sunny slopes—under stones, and about the roots of herbage, especially near springs, on shrubs and low trees, and so forth; for upon a knowledge of the plants and insects of mountain ranges depend many curious questions on the geographical distribution of forms over the earth. In reptiles, the smaller Batrachia (frogs, salamanders, &c.) should not be neglected, especially the extremely numerous family of tree-frogs; lizards may be caught generally with the insect sweeping-net; the arboreal species seen out of reach may be brought down with a charge of dust-shot. Snakes should be taken without injuring the head, which is the most important part of the body; a cleft stick may be used in securing them by the neck, and on reaching camp they may be dropped into the jars of spirits. As large a collection as possible should be made of the smaller fishes of inland lakes and unexplored rivers; Dr. Gunther, of the British Museum, has authorised me to say that a traveller cannot fail to make a large number of interesting discoveries if he collects a few specimens of the species he meets with in the lakes and rivers of the interior of any country.

It can scarcely be expected that specimens of the larger animals can be brought away by a geographical expedition, although some species are still desiderata in the large museums of Europe. Additional specimens of all genera, of which there are numerous closely-allied species (*e.g.* rhinoceros, antelope, equus, &c.) would be very welcome for the better discrimination of the species. If only portions can be obtained, skulls are to be preferred. In humid tropical regions entire skins cannot be dried in time to prevent decay, and it is necessary to place them, rolled up in small compass, in spirits. The smaller mammals, of which there remain many to reward the explorer in almost all extra-European countries, may be skinned, dried, and packed in boxes in the same manner as birds. The smaller birds shot on an excursion should be carried to camp in the game-bag, folded in paper, the wounds, mouth, and anus being first plugged with cotton. Powdered calcined gypsum will here be found very useful in absorbing blood from feathers, on account of the facility with which it can be afterwards cleared from the specimens. All plants, when gathered, are placed in the tin box which the traveller carries with him. Land and fresh-water shells may be carried home in a bag. All hard-bodied insects, such as beetles, ants, and so forth, should be placed, in collecting, in small bottles; each bottle having a small piece of slightly-moistened rag placed within it, to prevent the insects from crowding and injuring each other. The hint previously given with regard to number of specimens must be repeated here. *Take as great a variety of species as possible.* The sweeping-net should be freely used (except in very wet weather) in sweeping and beating the herbage and lower trees. In collecting ants, it is necessary to open nests and secure the winged individuals of each species, which must be afterwards kept together with the wingless ones to secure the identification of the species. Bees and wasps may be caught in the net and then placed, by means of small forceps, in the collecting-bottle and afterwards killed in the same way as beetles and other hard-bodied insects. All soft-bodied insects should be killed on capture (by a slight pressure of the chest underneath the wings by thumb and finger) and then pinned in the pocket collecting-box. If the traveller has leisure and inclination for the pursuit, he may readily make a large and varied collection of these, and will do good service to science if he notes carefully the exact localities of his captures, altitude above the sea, nature of country, the sexes of the species (if detected), and information on habits. The delicate species should be handled very carefully and put away into the drying-cage immediately on return from an excursion. Spiders may be collected in bottles, and afterwards killed and pinned in the same way as other insects. Crustacea (shrimps, crawfish, &c.) in rivers and pools may be collected with the landing-net, and afterwards well dried and pinned like hard-bodied insects, except when they are large in size, when their bodies must be opened and emptied of their contents.

Preserving and Packing.—Previous to skinning a small mammal or bird, make a note of the colour of its eyes and soft parts, and, if time admits, of the dimensions of its trunk and limbs. It facilitates skinning of birds to break, before commencing, the first bone of the wings a short distance above the joint, which causes the members to lie open when the specimen is laid on its back on the skinning-board. The animal should be laid with its tail towards the right hand of the operator, and the incision made from the breast-bone, nearly to the anus. A blunt wooden style is useful in commencing the operation of separating the skin from the flesh. When the leg is reached, cut through the knee-joint and then clear the flesh from the shank as far as can be done, afterwards washing the bone slightly with arsenical soap, winding a thin strip of cotton round it, and returning it to the skin. Repeat the process with the other leg, and then sever, with the broad-bladed scissors, the spine above the root of the tail. By carefully cutting into the flesh from above, the spine is finally severed without injuring the skin of the back, and it is then easy to continue the skinning up to the wings, when the bones are cut through at the place where they had previously been broken, and the body finished as far as the commencement of the skull. A small piece of the skull is now cut away, together with the neck and body, and the brains and eyes scooped out, the inside washed with the soap and clean cotton filled in, the eyes especially being made plump. In large-headed parrots, wood-peckers, and some other birds, the head cannot thus be cleaned; an incision has, therefore, to be made either on one side or on the back of the neck, through which the back of the skull can be thrust a little away and then cleansed, the incision being afterward closed by two or three stitches. The bones then remaining in each wing must be cleaned, which must be done without loosening the quill-feathers. It is much better to take out the flesh by making an incision on the outside of the skin along the flesh on the inner side of the wing. The inside of the skin must now be washed with the soap, and a neck of cotton (not too thick) inserted by means of the long narrow forceps, taking care to fix the end well inside the skull and withdrawing the empty forceps without stretching the skin of the neck and thus distorting the shape of the bird. Skins need not be filled up with cotton or any other material, but laid, with the feathers smoothed down, on the boards of the drying-cage until they are ready to be packed in boxes. In very humid climates like that of Tropical America, oxide of arsenic in powder is preferable to arsenical soap, on account of the skins drying quicker; but it cannot be recommended to the general traveller, owing to the danger attending its use.

In mammals the tail offers some difficulty to a beginner. To skin it, the root (after severing it from the spine) should be secured by a piece of strong twine, which should then be attached to a nail or beam: with two pieces of flat wood (one placed on each side of the naked root), held firmly by the hand and pulled downwards, the skin is made rapidly to give way generally to the tip. The tails of some animals, however, can be skinned only by incisions made down the middle from the outside. The larger mammal skins may be inverted, and, after washing with the soap, dried in the sun : as before remarked, it is often necessary to roll them up and preserve in spirit.

The skins of small mammals and birds, after they are *quite* dry, may be packed in boxes, which must be previously well washed inside with arsenical soap, lined with paper, and again covered with a coating of the soap and well dried in the sun. This is the very best means of securing the specimens from the attacks of noxious insects, which so often, to the great disgust of the traveller, destroy what he has taken so much pains to procure. Where wood is scarce, as in the interior of Africa, boxes may be made of the skins of antelopes or other large animals by stretching them, when newly stripped from the animal, over a square framework of sticks, and sewing up the edges: after being dried in the sun they make excellent packing-cases.

With regard to reptiles and fishes, I cannot do better than quote the following remarks sent me by Mr. Osbert Salvin, who collected these animals most successfully in Guatemala :—

" Almost any spirit will answer for this purpose, its fitness consisting in the amount of alcohol contained in it. In all cases it is best to procure the strongest possible, being less bulky, and water can always be obtained to reduce the strength to the requisite amount. When the spirit sold retail by the natives is not sufficiently strong, by visiting the distillery the traveller can often obtain the first runnings (the strongest) of the still, which will be stronger than he requires undiluted. The spirit used should be reduced to about proof, and the traveller should always be provided with an alcoholometer. If this is not at hand, a little practice will enable him to ascertain the strength of the spirit from the rapidity with which the bubbles break when rising to the surface of a small quantity shaken in a bottle. When the spirit has been used this test is of no value. When animals or fish are first immersed, it will be found that the spirit becomes rapidly weaker. Large specimens absorb the alcohol very speedily. The rapidity with which this absorption takes place should be carefully watched, and in warm climates the liquid tested at least every twelve hours, and fresh spirit added to restore it to its original strength. In colder climates it is not requisite to watch so closely, but practice will show what attention is necessary. It will be found that absorption of alcohol will be about proportionate to the rate of decomposition. Spirit should not be used too strong, as its effect is to contract the outer surface, and thus, closing the pores, prevent the alcohol from penetrating through to the inner parts of the specimen. *The principal point, then, is to watch that the strength of the spirit does not get below a certain point while the specimen is absorbing alcohol when first put in.* It will be found that after two or three days the spirit retains its strength: when this is the case, the specimen will be perfectly preserved. Spirit should not be thrown away, no matter how often used, so long as the traveller has a reserve of sufficient strength to bring it back to its requisite strength.

"In selecting specimens for immersion, regard must be had to the means at the traveller's disposal. Fish up to 9 inches long may be placed in spirit, with simply a slit cut to allow the spirit to enter to the entrails. With larger specimens, it is better to pass a long knife outside the ribs, so as to separate the muscles on each side of the vertebræ. It is also as well to remove as much food from the entrails as possible, taking care to leave all these in. The larger specimens can be skinned, leaving, however, the intestines in, and simply removing the flesh. Very large specimens preserved in this way absorb very little spirit. All half-digested food should be removed from snakes and animals. In spite of these precautions, specimens will often appear to be decomposing; but by more constant attention to re-strengthening the spirit, they will, in most cases, be preserved.

"A case (copper is the best), with a top that can be unscrewed and refixed easily, should always be carried as a receptacle. The opening should be large enough to allow the hand to be inserted; this is to hold freshly-caught specimens. When they have become preserved, they can all be removed and soldered up in tin or zinc boxes. Zinc is best, as it does not corrode so easily. The traveller will find it very convenient to take lessons in soldering, and so make his own boxes. If he takes them ready made, they had best be arranged so as to fit one into another before they are filled. When moving about, all specimens should be wrapped in calico or linen or other rags to prevent their rubbing one against the other. This should also be done to the specimens in the copper case when a move is necessary, as well as to those finally packed for transmission to Europe. These last should have all the interstices between the specimens filled in with cotton-wool or rags. If a leak should occur in a case, specimens thus packed will still be maintained moist, and will keep some time without much injury. Proof spirit should be used when the specimens are finally packed, but it is not necessary that it should be fresh."

Land and fresh-water shells, on reaching camp, should be placed in a basin of cold water to entice the animals out, and then, after draining off, killed by pouring boiling water over them. They may be cleared of flesh by means of a strong pin or penknife. The operculum or mouthpiece of all shells which possess it should be preserved and placed inside the empty shell. Each shell, when dry, should be wrapped in a piece of paper and the collection packed in a box, well padded with cotton or other dry and elastic material.

The insects collected on an excursion should be attended to immediately on arrival in camp. When leisure and space are limited all the hard-bodied ones may be put in bottles of spirit; and each bottle, when nearly full, should be filled up to the cork with a piece of rag, to prevent injury from shaking. Many species, however, become stained by spirit, and it is far better in dry countries, such as Africa, Australia, and Central Asia, to preserve all the hard-bodied ones in a dry state in pill-boxes. They are killed, whilst in the collecting-bottles, by plunging, for a few moments, the bottom half of the bottles in hot water. An hour afterwards the contents are shaken out over blotting-paper and put into pill-boxes—the bottom of the boxes being padded with cotton, over which is placed a circular piece of blotting-paper. The open pill-boxes should then be placed in the drying-cage for a day or two and then filled up with more cotton, the layer of insects being first covered by a circular piece of paper.* The soft-bodied specimens, which are brought home pinned, should be stuck in the drying-cage until they are dry, and then be pinned very close together in the store-boxes. The store-boxes, both bottom and sides, should each have inside a coating of arsenical soap before they are corked, and as they become filled, one by one, should be washed outside with the soap and pasted all over with paper. Camphor and other preservatives are of little or no use in tropical climates. In some countries where the traveller may wish to make a collection of the butterfly fauna, the best way is to preserve all the specimens in little paper envelopes. He should be careful not to press the insects too flat, simply killing them by pressure underneath the breast, folding their wings carefully backwards and slipping each into its envelope. In very humid tropical countries, such as the river valleys of Tropical America and the islands of the Eastern Archipelago, the plan of stowing away even hard-bodied insects in pill-

* The only preservative needed is a diluted wash of arsenical soap inside the pill-boxes, which, as in all other cases when soap is used, must be well dried afterwards, before the boxes are filled.

boxes does not answer, on account of the mould with which they soon become covered. There are, then, only two methods that can be adopted: one, preserving them at once in spirits; the other, pinning all those over a quarter of an inch long (running the pin through the right wing-case so as to come out beneath, between the second and third pair of legs); and gumming those of smaller size on small sheets of card, cut of uniform size so as to fit perpendicularly in racked boxes, like those used to contain microscopical slides, but larger. The cards may be a few inches square, and each may hold several scores of specimens, very lightly gummed down a short distance apart. After the cards are filled they should be well dried, and the box containing them washed outside with arsenical soap and pasted over with paper. All the pinned specimens should be placed to dry for a few days in the drying-cage and afterwards pinned very close together in the corked store-boxes.

Plants are dried by pressure, by means of the boards and straps, between sheets of botanical drying-paper—the paper requiring to be changed three or four times. When dry, the specimens may be placed between sheets of old newspapers, together with the notes the traveller may have made upon them, each placed upon the object to which it refers. Bundles of papers containing plants are not of difficult carriage; but they require to be guarded against wet, especially in fording rivers and in rainy weather, and should be wrapped in skins or india-rubber sheeting* until they can be safely packed in wooden boxes and despatched to Europe. Seeds may be collected when quite ripe and preserved in small packets of botanical paper, with a number written on referring to preserved specimens of the flowers. Dry fruits and capsules should be collected when in countries not previously explored by botanists, if the traveller has means of identifying the species to which they belong.

Fossils.—The collection of fossils and minerals (except in the case of the discovery of new localities for valuable metals) is not to be recommended to the traveller, if he is not a Geologist. Fossils from an unexplored country are of little use unless the nature and order of superposition of the strata in which they are found can be at the same time

* Waxed paper will be found very serviceable in excluding the air and damp from parcels. It is made by spreading a sheet of writing-paper on a hot plate or stone, and smearing it with wax. A hot flat-iron is convenient for making it (Galton's 'Art of Travel,' 4th edition, p. 323).

investigated. In the cases, however, of recent alluvial strata or the supposed beds of ancient lakes, or deposits in caves, or raised sea-beaches containing shells or bones of vertebrate animals, the traveller will do well to bring away specimens if a good opportunity offers. If the plan of the expedition includes the collection of fossil remains, the traveller will, of course, provide himself with a proper geological outfit, and obtain the necessary instructions before leaving Europe.

All collections made in tropical countries should be sent to Europe with the least possible delay, as they soon become deteriorated or spoilt unless great care be bestowed upon them. Dry skins of animals and birds may be packed in wooden cases simply with sheets of paper to separate the skins. Shells and skulls should be provided with abundance of elastic padding, such as cotton. The boxes containing insects and crustacea should be placed in the middle of large boxes surrounded by an ample bed of hay or other light dry elastic material; if this last point be not carefully attended to, it will be doubtful whether such collections will sustain a voyage without much injury.

Travellers have excellent opportunities of observing the habits of animals in a state of nature, and these hints would be very deficient were not a few words said upon this subject. To know what to observe in the economy of animals is in itself an accomplishment which it would be unreasonable to expect the general traveller to possess, and without this he may bring home only insignificant details, contributing but little to our stock of knowledge. One general rule, however, may be kept always present to the mind, and this is, that anything concerning animals which bears upon the relations of species to their conditions of life is well worth observing and recording. Thus, it is important to note the various enemies which each species has to contend with, not only at one epoch in its life, but at every stage from birth to death, and at different seasons and in different localities. The way in which the existence of enemies limits the range of a species should also be noticed. The inorganic influences which inimically affect species, especially intermittently (such as the occurrence of disastrous seasons), and which are likely to operate in limiting their ranges, are also important subjects of inquiry. The migrations of animals, and especially any facts about the irruption of species into districts previously uninhabited by them, are well worth recording. The food of each species should be noticed, and if any change of customary food is observed, owing to the failure of the supply, it should be carefully recorded. The use in nature of any peculiar physical conformation of animals, the object of ornamentation, and so forth, should also be investigated whenever opportunity occurs. Any facts relating to the interbreeding in a state of nature of allied varieties, or the converse—that is, the antipathy to intercoursing of allied varieties—would be extremely interesting. In short, the traveller should bear in mind that facts having a philosophical bearing are much more important than mere anecdotes about animals.

To observe the actions of the larger animals, a telescope or opera-glass will be necessary, and the traveller should bear in mind, if a microscope is needed in his journey, that by unscrewing the tubes of the telescope in which all the small glasses are contained, a compound microscope of considerable power is produced.

Tables.

A few Tables are now given, for the most part such as are to be found in works on navigation, or else in the Nautical Almanac of the present and three subsequent years. They are selected with the view of enabling a traveller on a detached expedition to take with him, in a compact form, the most necessary information. He can, by their aid, calculate accurate latitudes from meridian observations of stars, and fair ones (within one or two miles) from meridian observations of the sun. The Table of sun's mean right ascension, and that of semidiurnal arcs, will enable him to utilise his rough knowledge of local time derived from the meridian altitude of the sun, or from sunset in a level country, in calculating when any star that he may wish to observe will be on the meridian.

INDEX TO THE TABLES.

I. Mean Places of the principal Fixed Stars for January 1st, 1878.

Name.	Mag.	Right Asc.	Ann.Var	Declination.	Ann. Var.
		h. m.	s.	° ′	″
α Andromedæ ... Alpheratz	2	0 2	+3	28 25 N.	+ 20
γ Pegasi .... Algenib	2,3	0 7	3	14 30 N.	+ 20
α Cassiopeæ	var.	0 34	3	55 52 N.	+ 20
β Ceti	2	0 37	3	18 39 N.	+ 20
α Ursæ Minoris ... Polaris	2	1 14	21	88 40 N.	+ 19
α Eridani ... Achernar	1	1 33	2	57 51 S.	+ 18
α Arietis	2	2 00	3	22 53 N.	+ 17
α Persei	2	3 16	4	49 26 N.	+ 13
α Tauri .... Aldebaran	1	4 29	+3	16 16 N.	+ 8
α Aurigæ ... Capella	1	5 8	4	45 52 N.	+ 4
β Orionis ... Rigel	1	5 9	3	8 21 S.	+ 4
β Tauri	2	5 19	4	28 30 N.	+ 3
α Columbæ	2	5 35	2	34 8 S.	+ 2
α Orionis .... Betelguese	var.	5 49	3	7 23 N.	+ 1
α Argûs ... Canopus	1	6 21	1	52 38 S.	— 2
α Canis Majoris .... Sirius	1	6 40	3	16 33 S.	— 5
ε Canis Majoris	1,2	6 54	2	28 48 S.	— 5
α² Geminorum ... Castor	1,2	7 27	4	32 9 N.	— 8
α Canis Minoris ... Procyon	1	7 33	+3	5 32 N.	— 9
β Geminorum ... Pollux	1,2	7 38	4	28 19 N.	— 8
ι Argûs	2	9 14	2	58 46 S.	— 15
α Hydræ ... Alphard	2	9 22	3	8 8 S.	— 15
α Leonis ... Regulus	1,2	10 2	3	12 34 N.	— 17
η Argûs	1,2	10 40	2	59 3 S.	— 19
α Ursæ Majoris .... Dubhe	1,2	10 56	4	62 25 N.	— 19
β Leonis	2	11 43	3	15 15 N.	— 20
γ Ursæ Majoris	2,3	11 47	3	54 22 N.	— 20
α¹ Crucis	1	12 20	+3	62 25 S.	— 20
α Virginis ... Spica	1	13 19	3	10 31 S.	— 19
η Ursæ Majoris	2	13 43	2	49 55 N.	— 18
β Centauri	1	13 55	4	59 47 S.	— 18
α Boötis .... Arcturus	1	14 10	3	19 49 N.	— 19
α² Centauri	1	14 31	4	60 20 S.	— 15
α Coronæ Borealis ... Alphacca	2	15 29	3	27 8 N.	— 12
β¹ Scorpii	2	15 58	+3	19 28 S.	— 10
α Trianguli Australis	2	16 36	6	68 48 S.	— 3
α Ophiuchi	2	17 29	3	12 39 N.	— 3
α Lyræ .... Vega	1	18 33	2	38 40 N.	+ 3
α Pavonis	2	20 16	5	57 7 S.	+ 11
α Gruis	2	22 1	4	47 33 S.	+ 17
α Piscis Australis ... Fomalhaut	1,2	22 51	3	30 16 S.	+ 19
α Pegasi .... Markab	2	22 59	3	14 33 N.	+ 19

The mean places may be reduced for any subsequent year by applying, as directed in the table, the annual variation in Right Ascension, and in Declination, multiplied by the number of years exceeding 1878.

II. Declination of the Sun for the Years 1878 and 1882 at apparent noon at Greenwich.*

Day.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	23 0 S.	17 3 S.	7 31 S.	4 36 N.	15 7 N.	22 5 N.	23 7 N.	18 0 N.	8 15 N	3 14 S.	14 29 S.	21 51 S.
2	22 25	16 46	7 8	4 59	15 25	22 13	23 3	17 45	7 53	3 38	14 48	22 0
3	22 49	16 28	6 45	5 22	15 43	22 20	22 58	17 29	7 31	4 1	15 7	22 8
4	22 43	16 10	6 22	5 45	16 1	22 28	22 53	17 14	7 9	4 24	15 26	22 17
5	22 36	15 52	5 59	6 8	16 18	22 34	22 48	16 57	6 47	4 47	15 44	22 24
6	22 29	15 34	5 36	6 31	16 35	22 41	22 42	16 41	6 24	5 10	16 2	22 32
7	22 22	15 15	5 12	6 53	16 51	22 47	22 36	16 24	6 2	5 33	16 20	22 39
8	22 14	14 56	4 49	7 16	17 8	22 52	22 29	16 7	5 39	5 56	16 38	22 46
9	22 5	14 37	4 26	7 38	17 24	22 57	22 22	15 50	5 17	6 19	16 55	22 51
10	21 56	14 17	4 2	8 0	17 40	23 2	22 14	15 33	4 54	6 42	17 12	22 57
11	21 47	13 58	3 39	8 22	17 55	23 6	22 7	15 15	4 31	7 5	17 29	23 2
12	21 37	13 38	3 15	8 44	18 10	23 10	21 58	14 57	4 8	7 27	17 45	23 6
13	21 27	13 18	2 51	9 6	18 25	23 14	21 50	14 39	3 45	7 50	18 1	23 11
14	21 17	12 57	2 28	9 28	18 40	23 17	21 41	14 21	3 22	8 12	18 17	23 14
15	21 6	12 37	2 4	9 49	18 54	23 20	21 32	14 2	2 59	8 34	18 32	23 18
16	20 54	12 16	1 40	10 11	19 8	23 22	21 22	13 43	2 36	8 57	18 47	23 20
17	20 43	11 55	1 17	10 32	19 22	23 24	21 12	13 24	2 13	9 19	19 2	23 23
18	20 31	11 34	0 53	10 53	19 35	23 25	21 1	13 5	1 49	9 40	19 17	23 25
19	20 18	11 13	0 29	11 14	19 48	23 26	20 51	12 45	1 26	10 2	19 3	23 26
20	20 5	10 51 S.	0 6	11 34	20 1	23 27	20 40	12 25	1 3	10 24	19 45	23 27
21	19 52	10 29 N.	0 18	11 55	20 13	23 27	20 28	12 5	0 40	10 45	19 58	23 27
22	19 38	10 8	0 42	12 15	20 25	23 27	20 16	11 45	0 16	11 7	20 11	23 27
23	19 24	9 46	1 5	12 35	20 37	23 27	20 4	11 25	0 7 S.	11 28	20 24	23 27
24	19 10	9 24	1 29	12 55	20 48	23 26	19 52	11 5	0 31	11 49	20 36	23 26
25	18 55	9 1	1 53	13 14	20 59	23 24	19 39	10 44	0 54	12 9	20 48	23 24
26	18 40	8 39	2 16	13 34	21 9	23 22	19 26	10 23	1 17	12 30	20 59	23 22
27	18 26	8 17	2 40	13 53	21 20	23 20	19 12	10 2	1 41	12 51	21 10	23 20
28	18 9	7 54	3 3	14 12	21 29	23 18	18 59	9 41	2 4	13 11	21 21	23 17
29	17 53	..	3 27	14 31	21 39	23 14	18 44	9 20	2 28	13 31	21 31	23 14
30	17 37	..	3 50	14 49	21 48	23 11	18 30	8 58	2 51	13 51	21 41	23 10
31	17 20	..	4 13	..	21 57	..	18 15	8 36	..	14 10	..	23 6

* The declination for the years 1878–79–80 and 81 are to the nearest minute. The declination for the years 1882–83–84 and 85 are almost equally correct; even for the next term of four years, 1886, 1878, 1888, 1889, the greatest error little exceeds a single minute.

II. *continued.*—Declination of the Sun for the Years 1879 and 1883 at apparent noon at Greenwich.

Day.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	′	° ′	° ′
1	23 1 S.	17 7 S.	7 36 S.	4 31 N.	15 3 N.	22 3 N.	23 8 N.	18 4 N.	8 20 N.	3 9 S.	14 25 S.	21 48 S.
2	22 56	16 50	7 14	4 54	15 21	22 11	23 4	17 49	7 58	3 32	14 44	21 58
3	22 50	16 32	6 51	5 17	15 39	22 19	22 59	17 33	7 36	3 55	15 3	22 6
4	22 44	16 14	6 28	5 40	15 56	22 26	22 54	17 17	7 14	4 18	15 21	22 15
5	22 38	15 56	6 4	6 3	16 14	22 33	22 49	17 1	6 52	4 42	15 40	22 23
6	22 31	15 38	5 41	6 25	16 31	22 39	22 43	16 45	6 30	5 5	15 58	22 30
7	22 23	15 19	5 18	6 48	16 47	22 45	22 37	16 28	6 7	5 28	16 16	22 37
8	22 16	15 1	4 55	7 10	17 4	22 51	22 30	16 12	5 45	5 51	16 33	22 44
9	22 7	14 41	4 31	7 33	17 20	22 56	22 23	15 54	5 22	6 14	16 51	22 50
10	21 58	14 22	4 8	7 55	17 36	23 1	22 16	15 37	4 59	6 36	17 8	22 55
11	21 49	14 2	3 44	8 17	17 51	23 5	22 8	15 19	4 37	6 59	17 25	23 1
12	21 40	13 43	3 21	8 39	18 7	23 9	22 0	15 1	4 14	7 22	17 41	23 5
13	21 30	13 23	2 57	9 1	18 22	23 13	21 52	14 43	3 51	7 44	17 57	23 10
14	21 19	13 2	2 33	9 23	18 36	23 16	21 43	14 25	3 28	8 7	18 13	23 13
15	21 8	12 42	2 10	9 44	18 51	23 19	21 34	14 6	3 5	8 29	18 29	23 17
16	20 57	12 21	1 46	10 5	19 5	23 21	21 24	13 47	2 41	8 51	18 44	23 20
17	20 46	12 0	1 22	10 27	19 19	23 23	21 14	13 29	2 18	9 13	18 59	23 22
18	20 34	11 39	1 59	10 48	19 32	23 25	21 4	13 9	1 55	9 35	19 13	23 24
19	20 21	11 18	0 35	11 9	19 45	23 26	20 53	12 50	1 32	9 57	19 27	23 26
20	20 8	10 56	0 11 S.	11 29	19 58	23 27	20 42	12 30	1 8	10 19	19 41	23 27
21	19 55	10 35	0 12 N.	11 50	20 10	23 27	20 31	12 10	0 45	10 40	19 55	23 27
22	19 42	10 13	0 36	12 10	20 22	23 27	20 19	11 50	0 22 N.	11 2	20 8	23 27
23	19 28	9 51	1 0	12 30	20 34	23 27	20 7	11 30	0 2 S.	11 23	20 21	23 27
24	19 13	9 29	1 23	12 50	20 45	23 26	19 55	11 9	0 25	11 44	20 33	23 26
25	18 59	9 7	1 47	13 10	20 56	23 25	19 42	10 49	0 48	12 5	20 45	23 25
26	18 44	8 44	2 11	13 29	21 7	23 23	19 29	10 28	1 12	12 25	20 56	23 23
27	18 28	8 22	2 34	13 48	21 17	23 21	19 16	10 7	1 35	12 46	21 8	23 21
28	18 13	7 59	2 58	14 7	21 27	23 18	19 2	9 46	1 59	13 6	21 18	23 18
29	17 57	..	3 21	14 26	21 37	23 15	18 48	9 25	2 22	13 26	21 29	23 15
30	17 41	..	3 44	14 45	21 46	23 12	18 34	9 3	2 45	13 46	21 39	23 11
31	17 24	..	4 8	..	21 55	..	18 19	8 42	..	14 5	..	23 7

II. *continued.*—Declination of the Sun for the Years 1880 and 1884 at apparent noon at Greenwich.

Day.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	23 2 S.	17 11 S.	7 19 S.	4 48 N.	15 17 N.	22 9 N.	23 5 N.	17 52 N.	8 4 N.	3 26 S.	14 39 S.	21 55 S.
2	22 57	16 54	6 56	5 11	15 35	22 17	23 0	17 37	7 42	3 50	14 58	22 4
3	22 52	16 37	6 33	5 34	15 52	22 24	22 56	17 21	7 20	4 13	15 17	22 13
4	22 46	16 19	6 10	5 57	16 10	22 31	22 50	17 5	6 57	4 36	15 35	22 21
5	22 39	16 1	5 47	6 20	16 27	22 38	22 45	16 49	6 35	4 59	15 54	22 28
6	22 32	15 42	5 24	6 42	16 43	22 44	22 38	16 32	6 13	5 22	16 12	22 35
7	22 25	15 24	5 0	7 5	17 0	22 49	22 32	16 16	5 50	5 45	16 29	22 42
8	22 17	15 5	4 37	7 27	17 16	22 55	22 25	15 59	5 28	6 8	16 47	22 48
9	22 9	14 46	4 13	7 50	17 32	23 0	22 18	15 41	5 5	6 31	17 4	22 54
10	22 1	14 27	3 50	8 12	17 48	23 4	22 10	15 24	4 42	6 54	17 21	22 59
11	21 52	14 7	3 26	8 34	18 3	23 8	22 2	15 6	4 19	7 16	17 37	23 4
12	21 42	13 47	3 3	8 56	18 18	23 12	21 54	14 48	3 56	7 39	17 53	23 9
13	21 32	13 27	2 39	9 17	18 33	23 15	21 45	14 29	3 33	8 1	18 9	23 12
14	21 22	13 7	2 15	9 39	18 47	23 18	21 36	14 11	3 10	8 24	18 25	23 16
15	21 11	12 47	1 52	10 0	19 2	23 21	21 26	13 52	2 47	8 46	18 40	23 19
16	21 0	12 26	1 28	10 22	19 15	23 23	21 17	13 33	2 24	9 8	18 55	23 22
17	20 48	12 5	1 4	10 43	19 29	23 25	21 6	13 14	2 1	9 30	19 10	23 24
18	20 36	11 44	0 41	11 4	19 42	23 26	20 56	12 54	1 37	9 52	19 24	23 25
19	20 24	11 23	0 17 S.	11 24	19 55	23 27	20 45	12 35	1 14	10 13	19 38	23 26
20	20 11	11 1	0 7 N.	11 45	20 7	23 27	20 34	12 15	0 51	10 35	19 51	23 27
21	19 58	10 40	0 30	12 5	20 19	23 27	20 22	11 55	0 28	10 56	20 5	23 27
22	19 45	10 18	0 54	12 25	20 31	23 27	20 10	11 35	0 4 N.	11 17	20 17	23 27
23	19 31	9 56	1 18	12 45	20 43	23 26	19 58	11 14	0 19 S.	11 39	20 30	23 26
24	19 17	9 34	1 41	13 5	20 54	23 25	19 45	10 54	0 43	11 59	20 42	23 25
25	19 2	9 12	2 5	13 24	21 4	23 23	19 32	10 33	1 6	12 20	20 54	23 23
26	18 47	8 50	2 28	13 44	21 15	23 21	19 19	10 12	1 29	12 41	21 5	23 21
27	18 32	8 27	2 52	14 3	21 25	23 19	19 5	9 51	1 53	13 1	21 16	23 19
28	18 17	8 5	3 15	14 22	21 34	23 16	18 51	9 30	2 16	13 21	21 26	23 15
29	18 1	7 42	3 39	14 40	21 44	23 13	18 37	9 9	2 40	13 41	21 36	23 12
30	17 44	..	4 2	14 59	21 52	23 9	18 22	8 47	3 3	14 1	21 46	23 8
31	17 28	..	4 25	..	22 1	..	18 8	8 25	..	14 20	..	23 3

II. *continued.*—Declination of the Sun for the Years 1881 and 1885 at apparent noon at Greenwich.

Day.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1	22 58 S.	16 58 S.	7 25 S.	4 42 N.	15 12 N.	22 7 N.	23 6 N.	17 56 N.	8 9 N.	3 21 S.	14 35 S.	21 53 S.
2	22 53	16 41	7 2	5 6	15 30	22 15	23 1	17 41	7 47	3 44	14 54	22 2
3	22 47	16 23	6 39	5 29	15 48	22 22	22 57	17 25	7 25	4 7	15 12	22 11
4	22 41	16 5	6 16	5 51	16 5	22 29	22 51	17 9	7 3	4 31	15 31	22 19
5	22 34	15 47	5 53	6 14	16 22	22 36	22 46	16 53	6 40	4 54	15 49	22 26
6	22 27	15 29	5 29	6 37	16 39	22 42	22 40	16 36	6 18	5 17	16 7	22 34
7	22 19	15 10	5 6	6 59	16 56	22 48	22 34	16 20	5 56	5 40	16 25	22 40
8	22 11	14 51	4 43	7 22	17 12	22 53	22 27	16 3	5 33	6 3	16 43	22 47
9	22 3	14 32	4 19	7 44	17 28	22 59	22 20	15 45	5 10	6 26	17 0	22 53
10	21 54	14 12	3 56	8 6	17 44	23 3	22 12	15 28	4 48	6 48	17 17	22 58
11	21 44	13 52	3 32	8 28	17 59	23 7	22 4	15 10	4 25	7 11	17 33	23 3
12	21 35	13 32	3 9	8 50	18 14	23 11	21 56	14 52	4 2	7 34	17 50	23 7
13	21 24	13 12	2 45	9 12	18 29	23 15	21 47	14 34	3 39	7 56	18 6	23 12
14	21 14	12 52	2 21	9 34	18 44	23 18	21 38	14 15	3 16	8 18	18 21	23 15
15	21 3	12 31	1 58	9 55	18 58	23 20	21 29	13 57	2 53	8 41	18 37	23 18
16	20 51	12 10	1 34	10 16	19 12	23 22	21 19	13 38	2 29	9 3	18 52	23 21
17	20 39	11 49	1 10	10 37	19 25	23 24	21 9	13 19	2 6	9 25	19 6	23 23
18	20 27	11 28	0 47	10 58	19 39	23 26	20 58	12 59	1 43	9 47	19 21	23 25
19	20 15	11 7	0 22 S.	11 19	19 52	23 27	20 48	12 40	1 20	10 8	19 35	23 26
20	20 2	10 45	0 1 N.	11 40	20 4	23 27	20 36	12 20	0 56	10 30	19 48	23 27
21	19 48	10 24	0 24	12 0	20 16	23 27	20 25	12 0	0 33	10 51	20 1	23 27
22	19 34	10 2	0 48	12 20	20 28	23 27	20 13	11 40	0 10 N.	11 13	20 14	23 27
23	19 20	9 40	1 12	12 40	20 40	23 26	20 1	11 19	0 14 S.	11 34	20 27	23 26
24	19 6	9 18	1 35	13 0	20 51	23 25	19 48	10 59	0 37	11 55	20 39	23 25
25	18 51	8 55	1 59	13 20	21 2	23 24	19 35	10 38	1 1	12 15	20 51	23 24
26	18 36	8 33	2 22	13 39	21 12	23 22	19 22	10 17	1 24	12 36	21 2	23 22
27	18 20	8 10	2 46	13 58	21 22	23 19	19 8	9 56	1 47	12 56	21 13	23 19
28	18 5	7 48	3 9	14 17	21 32	23 17	18 55	9 35	2 11	13 16	21 24	23 16
29	17 49	7 25	3 33	14 36	21 41	23 13	18 40	9 14	2 34	13 36	21 34	23 13
30	17 32	..	3 56	14 54	21 50	23 10	18 26	8 52	2 58	13 56	21 44	23 9
31	17 15	..	4 19	..	21 59	..	18 11	8 30	..	14 16	..	23 4

III. Corrections for Refraction.

Mean Astronomical Refraction.
(Barom. 30 inches; Therm. 50° Fahr.)

App. Alt.	Refr.	App. Alt.	Refr.	App. Alt.	Refr.
° ′	′ ″	° ′	′ ″	° ′	′ ″
20 00	2 35	25 50	1 57	38 30	1 11
20 10	2 34	26 00	1 56	39 00	1 10
20 20	2 32	26 10	1 55	39 30	1 9
20 30	2 31	26 20	1 55	40 00	1 8
20 40	2 29	26 30	1 54	41 00	1 5
20 50	2 28	26 40	1 53	42 00	1 3
21 00	2 27	26 50	1 52	43 00	1 1
21 10	2 26	27 00	1 51	44 00	0 59
21 20	2 25	27 15	1 50	45 00	0 57
21 30	2 24	27 30	1 49	46 00	0 55
21 40	2 23	27 45	1 48	47 00	0 53
21 50	2 21	28 00	1 47	48 00	0 51
22 00	2 20	28 15	1 46	49 00	0 49
22 10	2 19	28 30	1 45	50 00	0 48
22 20	2 18	28 45	1 44	51 00	0 46
22 30	2 17	29 00	1 42	52 00	0 44
22 40	2 16	29 30	1 40	53 00	0 43
22 50	2 15	30 00	1 38	54 00	0 41
23 00	2 14	30 30	1 37	55 00	0 40
23 10	2 13	31 00	1 35	56 00	0 38
23 20	2 12	31 30	1 33	57 00	0 37
23 30	2 11	32 00	1 31	58 00	0 35
23 40	2 10	32 30	1 30	59 00	0 34
23 50	2 9	33 00	1 28	60 00	0 33
24 00	2 8	33 30	1 26	61 00	0 32
24 10	2 7	34 00	1 24	62 00	0 32
24 20	2 6	34 30	1 23	63 00	0 29
24 30	2 5	35 00	1 21	64 00	0 28
24 40	2 4	35 30	1 20	65 00	0 26
34 50	2 3	36 00	1 18	66 00	0 25
25 00	2 02	36 30	1 17	67 00	0 24
25 10	2 01	37 00	1 16	68 00	0 23
25 20	2 00	37 30	1 14	69 00	0 22
25 30	1 59	38 00	1 13	70 00	0 21
25 40	1 58				

Corrections when Barom. differs from 30 inches or Therm. from 50° Fahr.

Barometer.

App. Alt.	For each inch above or below 30 inches:—*add*, if above 30; *subtract*, if below.
°	″
20	5
25	4
30	3
35	3
40	2
45	2
50	2
55	1
60	1
65	1
70	1

Thermometer.

App. Alt.	For each degree above or below 50° Fahr.:—*subtract*, if above 50°; *add*, if below.
°	″
20	3
25	3
30	2
35	2
40	1
45	1
50	1
55	1
60	1
65	1
70	0

IV. Semidiurnal and Seminocturnal Arches, showing the time of the Rising and Setting of the Sun, Moon, or Stars.

Declination.

Lat.	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	Lat.
0	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	0
1	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 1	6 1	6 1	6 1	6 1	6 1	1
2	6 0	6 0	6 0	6 0	6 1	6 1	6 1	6 1	6 1	6 1	6 1	6 2	6 2	6 2	2
3	6 0	6 0	6 0	6 1	6 1	6 1	6 1	6 1	6 2	6 2	6 2	6 2	6 3	6 3	3
4	6 0	6 0	6 1	6 1	6 1	6 1	6 2	6 2	6 2	6 3	6 3	6 3	6 3	6 4	4
5	6 0	6 0	6 1	6 1	6 1	6 2	6 2	6 2	6 3	6 3	6 4	6 4	6 4	6 5	5
6	6 0	6 0	6 1	6 1	6 2	6 2	6 3	6 3	6 3	6 4	6 4	6 5	6 5	6 6	6
7	6 0	6 0	6 1	6 1	6 2	6 2	6 3	6 3	6 4	6 4	6 5	6 5	6 6	6 6	7
8	6 0	6 1	6 1	6 2	6 2	6 3	6 3	6 4	6 5	6 5	6 6	6 6	9 7	6 7	8
9	6 0	6 1	6 1	6 2	6 3	6 3	6 4	6 4	6 5	6 6	6 6	6 7	6 8	6 8	9
10	6 0	6 1	6 1	6 2	6 3	6 4	6 4	6 5	6 6	6 6	6 7	6 8	6 9	6 9	10
11	6 0	6 1	6 2	6 2	6 3	6 4	6 5	6 5	6 6	6 7	6 8	6 9	6 9	6 10	11
12	6 0	6 1	6 2	6 3	6 3	6 4	6 5	6 6	6 7	6 8	6 9	6 9	6 10	6 11	12
13	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 6	6 7	6 8	6 9	6 10	6 11	6 12	13
14	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 7	6 8	6 9	6 10	6 11	6 12	6 13	14
15	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 8	6 9	6 10	6 11	6 12	6 13	6 14	15
16	6 0	6 1	6 2	6 3	6 5	6 6	6 7	6 8	6 9	6 10	6 12	6 13	6 14	6 15	16
17	6 0	6 1	6 2	6 4	6 5	6 6	6 7	6 9	6 10	6 11	6 12	6 14	6 15	6 16	17
18	6 0	6 1	6 3	6 4	6 5	6 7	6 8	6 9	6 10	6 12	6 13	6 14	6 16	6 17	18
19	6 0	6 1	6 3	6 4	6 6	6 7	6 8	6 10	6 11	6 13	6 14	6 15	6 17	6 18	19
20	6 0	6 1	6 3	6 4	6 6	6 7	6 9	6 10	6 12	6 13	6 15	6 16	6 18	6 19	20
21	6 0	6 2	6 3	6 5	6 6	6 8	6 9	6 11	6 12	6 14	6 16	6 17	6 19	6 20	21
22	6 0	6 2	6 3	6 5	6 6	6 8	6 10	6 11	6 13	6 15	6 16	6 18	6 20	6 21	22
23	6 0	6 2	6 3	6 5	6 7	6 9	6 10	6 12	6 14	6 15	6 17	6 19	6 21	6 22	23
24	6 0	6 2	6 4	6 5	6 7	6 9	6 11	6 13	6 14	6 16	6 18	6 20	6 22	6 24	24
25	6 0	6 2	6 4	6 6	6 7	6 9	6 11	6 13	6 15	6 17	6 19	6 21	6 23	6 25	25
26	6 0	6 2	6 4	6 6	6 8	6 10	6 12	6 14	6 16	6 18	6 20	6 22	6 24	6 26	26
27	6 0	6 2	6 4	6 6	6 8	6 10	6 12	6 14	6 16	6 19	6 21	6 23	6 25	6 27	27
28	6 0	6 2	6 4	6 6	6 9	6 11	6 13	6 15	6 17	6 19	6 22	6 24	6 26	6 28	28
29	6 0	6 2	6 4	6 7	6 9	6 11	6 13	6 16	6 18	6 20	6 22	6 25	6 27	6 29	29
30	6 0	6 2	6 5	6 7	6 9	6 12	6 14	6 16	6 19	6 21	6 23	6 26	6 28	6 31	30
31	6 0	6 2	6 5	6 7	6 10	6 12	6 14	6 17	6 19	6 22	6 24	6 27	6 29	6 32	31
32	6 0	6 2	6 5	6 8	6 10	6 13	6 15	6 18	6 20	6 23	6 25	6 28	6 31	6 33	32
33	6 0	6 3	6 5	6 8	6 10	6 13	6 16	6 18	6 21	6 24	6 26	6 29	6 32	6 34	33
34	6 0	6 3	6 5	6 8	6 11	6 14	6 16	6 19	6 22	6 25	6 27	6 30	6 33	6 36	34
35	6 0	6 3	6 6	6 8	6 11	6 14	6 17	6 20	6 23	6 25	6 28	6 31	6 34	6 37	35
36	6 0	6 3	6 6	6 9	6 12	6 15	6 18	6 20	6 23	6 26	6 29	6 32	6 36	6 39	36
37	6 0	6 3	6 6	6 9	6 12	6 15	6 18	6 21	6 24	6 27	6 31	6 34	6 37	6 40	37
38	6 0	6 3	6 6	6 9	6 13	6 16	6 19	6 22	6 25	6 28	6 32	6 35	6 38	6 42	38
39	6 0	6 3	6 6	6 10	6 13	6 16	6 20	6 23	6 26	6 29	6 33	6 36	6 40	6 43	39
40	6 0	6 3	6 7	6 10	6 13	6 17	6 20	6 24	6 27	6 31	6 34	6 38	6 41	6 45	40
41	6 0	6 3	6 7	6 10	6 14	6 17	6 21	6 25	6 28	6 32	6 35	6 39	6 43	6 46	41
42	6 0	6 4	6 7	6 11	6 14	6 18	6 22	6 25	6 29	6 33	6 37	6 40	6 44	6 48	42
43	6 0	6 4	6 7	6 11	6 15	6 19	6 22	6 26	6 30	6 34	6 38	6 42	6 46	6 50	43
44	6 0	6 4	6 8	6 12	6 15	6 19	6 23	6 27	6 31	6 35	6 39	6 43	6 47	6 52	44
45	6 0	6 4	6 8	6 12	6 16	6 20	6 24	6 28	6 32	6 36	6 41	6 45	6 49	6 53	45
46	6 0	6 4	6 8	6 12	6 17	6 21	6 25	6 29	6 33	6 38	6 42	6 46	6 51	6 55	46
47	6 0	6 4	6 9	6 13	6 17	6 22	6 26	6 30	6 35	6 39	6 44	6 48	6 53	6 57	47
48	6 0	6 4	6 9	6 13	6 18	6 22	6 27	6 31	6 36	6 41	6 45	6 50	6 55	6 59	48
49	6 0	6 5	6 9	6 14	6 18	6 23	6 28	6 32	6 37	6 42	6 47	6 52	6 57	7 2	49
50	6 0	6 5	6 10	6 14	6 19	6 24	6 29	6 34	6 39	6 44	6 49	6 54	6 59	7 4	50
51	6 0	6 5	6 10	6 15	6 20	6 25	6 30	6 35	6 40	6 45	6 50	6 56	7 1	7 6	51
52	6 0	6 5	6 10	6 15	6 21	6 26	6 31	6 36	6 41	6 47	6 52	6 58	7 3	7 9	52
53	6 0	6 5	6 11	6 16	6 21	6 27	6 32	6 38	6 43	6 49	6 54	7 0	7 6	7 11	53
54	6 0	6 5	6 11	6 17	6 22	6 28	6 33	6 39	6 45	6 50	6 56	7 2	7 8	7 14	54
55	6 0	6 6	6 11	6 17	6 23	6 29	6 35	6 40	6 46	6 52	6 59	7 4	7 11	7 17	55
56	6 0	6 6	6 12	6 18	6 24	6 30	6 36	6 42	6 48	6 54	7 1	7 7	7 13	7 20	56
57	6 0	6 6	6 12	6 19	6 25	6 31	6 37	6 44	6 50	6 56	7 3	7 10	7 16	7 23	57
58	6 0	6 6	6 13	6 19	6 26	6 32	6 39	6 45	6 52	6 59	7 6	7 12	7 20	7 27	58
59	6 0	6 7	6 13	6 20	6 27	6 33	6 40	6 47	6 54	7 1	7 8	7 15	7 23	7 30	59
60	6 0	6 7	6 14	6 21	6 28	6 35	6 42	6 49	6 56	7 4	7 11	7 19	7 26	7 34	60

IV. Semidiurnal and Seminocturnal Arches, showing the time of the Rising and Setting of the Sun, Moon, and Stars—*continued.*

Declination.

Lat.	14°	15°	16°	17°	18°	19°	20°	21°	21½°	22°	22½°	23°	23° 23′	Lat.
0	h. m.	h. m.	h. m.	h. m	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	0
1	6 1	6 1	6 1	6 1	6 1	6 1	6 1	6 2	6 2	6 2	6 2	6 2	6 2	1
2	6 2	6 2	6 2	6 2	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	6 3	2
3	6 3	6 3	6 3	6 4	6 4	6 4	6 4	6 5	6 5	6 5	6 5	6 5	6 5	3
4	6 4	6 4	6 5	6 5	6 5	6 6	6 6	6 6	6 6	6 6	6 7	6 7	6 7	4
5	6 5	6 5	6 6	6 6	6 7	6 7	6 7	6 8	6 8	6 8	6 8	6 9	6 9	5
6	6 6	6 6	6 7	6 7	6 8	6 8	6 9	6 9	6 10	6 10	6 10	6 10	6 10	6
7	6 7	6 8	6 8	6 9	6 9	6 10	6 10	6 11	6 11	6 11	6 12	6 12	6 12	7
8	6 8	6 9	6 8	6 10	6 10	6 11	6 12	6 12	6 13	6 13	6 13	6 14	6 14	8
9	6 9	6 10	6 10	6 11	6 12	6 13	6 13	6 14	6 14	6 15	6 15	6 15	6 16	9
10	6 10	6 11	6 12	6 12	6 13	6 14	6 15	6 16	6 16	6 16	6 17	6 17	6 18	10
11	6 11	6 12	6 13	6 14	6 14	6 15	6 16	6 17	6 18	6 18	6 18	6 19	6 19	11
12	6 12	6 13	6 14	6 15	6 16	6 17	6 18	6 19	6 19	6 20	6 20	6 21	6 21	12
13	6 13	6 14	6 15	6 16	6 17	6 18	6 19	6 20	6 21	6 21	6 22	6 22	6 23	13
14	6 14	6 15	6 16	6 17	6 19	6 20	6 21	6 22	6 23	6 23	6 24	6 24	6 25	14
15	6 15	6 16	6 18	6 19	6 20	6 21	6 22	6 24	6 24	6 25	6 25	6 26	6 27	15
16	6 16	6 18	6 19	6 20	6 21	6 23	6 24	6 25	6 26	6 27	6 27	6 28	6 29	16
17	6 17	6 19	6 20	6 21	6 23	6 24	6 26	6 27	6 28	6 28	6 29	6 30	6 31	17
18	6 19	6 20	6 21	6 23	6 24	6 26	6 27	6 29	6 29	6 30	6 31	6 32	6 32	18
19	6 20	6 21	6 23	6 24	6 26	6 27	6 29	6 30	6 31	6 32	6 33	6 34	6 34	19
20	6 21	6 22	6 24	6 26	6 27	6 29	6 30	6 32	6 33	6 34	6 35	6 36	6 36	20
21	6 22	6 24	6 25	6 27	6 29	6 30	6 32	6 34	6 35	6 36	6 37	6 38	6 38	21
22	6 23	6 25	6 27	6 28	6 30	6 32	6 34	6 36	6 37	6 38	6 39	6 40	6 41	22
23	6 24	6 26	6 28	6 30	6 32	6 34	6 36	6 38	6 38	6 39	6 40	6 42	6 43	23
24	6 25	6 27	6 29	6 31	6 33	6 35	6 37	6 39	6 40	6 41	6 42	6 44	6 45	24
25	6 27	6 29	6 31	6 33	6 35	6 37	6 39	6 41	6 42	6 43	6 45	6 46	6 47	25
26	6 28	6 30	6 32	6 34	6 36	6 39	6 41	6 43	6 44	6 45	6 47	6 48	6 49	26
27	6 29	6 31	6 34	6 36	6 38	6 40	6 43	6 45	6 46	6 48	6 49	6 50	6 51	27
28	6 30	6 33	6 35	6 37	6 40	6 42	6 45	6 47	6 48	6 50	6 51	6 52	6 53	28
29	6 32	6 34	6 37	6 39	6 42	6 44	6 47	6 49	6 50	6 52	6 53	6 54	6 56	29
30	6 33	6 36	6 38	6 41	6 43	6 46	6 49	6 51	6 53	6 54	6 55	6 57	6 58	30
31	6 34	6 37	6 40	6 42	6 45	6 48	6 51	6 53	6 55	6 56	6 58	6 59	7 0	31
32	6 36	6 39	6 41	6 44	6 47	6 50	6 53	6 56	6 57	6 58	7 0	7 2	7 3	32
33	6 37	6 40	6 43	6 46	6 49	6 53	6 55	6 58	6 59	7 1	7 2	7 4	7 5	33
34	6 39	6 42	6 45	6 48	6 51	6 54	6 57	7 0	7 2	7 3	7 5	7 7	7 8	34
35	6 40	6 43	6 46	6 49	6 53	6 56	6 59	7 2	7 4	7 6	7 7	7 9	7 11	35
36	6 42	6 45	6 48	6 51	6 55	6 58	7 1	7 5	7 7	7 8	7 10	7 12	7 14	36
37	6 43	6 47	6 50	6 53	6 57	7 0	7 4	7 7	7 9	7 11	7 13	7 15	7 16	37
38	6 45	6 48	6 52	6 55	6 59	7 2	7 6	7 10	7 12	7 14	7 16	7 17	7 19	38
39	6 47	6 50	6 54	6 57	7 1	7 5	7 9	7 12	7 14	7 16	7 18	7 20	7 22	39
40	6 48	6 52	6 56	6 59	7 3	7 7	7 11	7 15	7 17	7 19	7 21	7 23	7 25	40
41	6 50	6 54	6 58	7 2	7 6	7 10	7 14	7 18	7 20	7 22	7 24	7 27	7 29	41
42	6 52	6 56	7 0	7 4	7 8	7 12	7 17	7 21	7 23	7 25	7 28	7 30	7 32	42
43	6 54	6 58	7 2	7 6	7 11	7 15	7 19	7 24	7 26	7 29	7 31	7 33	7 36	43
44	6 56	7 0	7 4	7 9	7 13	7 18	7 22	7 27	7 29	7 32	7 34	7 37	7 39	44
45	6 58	7 2	7 7	7 11	7 16	7 21	7 25	7 30	7 33	7 35	7 38	7 40	7 43	45
46	7 0	7 4	7 9	7 14	7 19	7 24	7 29	7 34	7 36	7 39	7 42	7 44	7 47	46
47	7 2	7 7	7 12	7 17	7 22	7 27	7 32	7 37	7 40	7 43	7 46	7 48	7 51	47
48	7 4	7 9	7 14	7 19	7 25	7 30	7 35	7 41	7 44	7 47	7 50	7 53	7 55	48
49	7 7	7 12	7 17	7 22	7 28	7 33	7 39	7 45	7 48	7 51	7 54	7 57	8 0	49
50	7 9	7 14	7 20	7 25	7 31	7 37	7 43	7 49	7 52	7 55	7 58	8 2	8 5	50
51	7 12	7 17	7 23	7 29	7 35	7 41	7 47	7 53	7 56	8 0	8 3	8 6	8 10	51
52	7 14	7 20	7 26	7 32	7 38	7 45	7 51	7 58	8 1	8 5	8 8	8 12	8 15	52
53	7 17	7 23	7 29	7 36	7 42	7 49	7 56	8 2	8 6	8 10	8 13	8 17	8 21	53
54	7 20	7 27	7 33	7 40	7 46	7 53	8 0	8 8	8 11	8 15	8 19	8 23	8 25	54
55	7 23	7 30	7 37	7 44	7 51	7 58	8 5	8 13	8 17	8 21	8 25	8 29	8 33	55
56	7 27	7 34	7 41	7 48	7 55	8 3	8 11	8 19	8 23	8 27	8 32	8 36	8 40	56
57	7 30	7 37	7 45	7 52	8 0	8 8	8 16	8 25	8 29	8 34	8 39	8 43	8 48	57
58	7 34	7 42	7 49	7 57	8 5	8 14	8 22	8 32	8 36	8 41	8 46	8 51	8 56	58
59	7 38	7 46	7 54	8 2	8 11	8 20	8 29	8 39	8 44	8 49	8 54	9 0	9 5	59
60	7 42	7 51	7 59	8 8	8 17	8 26	8 36	8 47	8 52	8 58	9 3	9 9	9 15	60

V. Sun's Mean Right Ascension.

Days.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
1	18 46	20 58	22 48	0 42	2 33	4 35	6 40	8 45	10 41	12 29	14 25	16 29
2	18 50	21 02	22 52	0 45	2 37	4 40	6 44	8 49	10 40	12 32	14 29	16 33
3	18 54	21 06	22 56	0 49	2 40	4 44	6 48	8 52	10 48	12 36	14 33	16 37
4	18 59	21 10	22 59	0 53	2 44	4 48	6 52	8 56	10 52	12 40	14 37	16 42
5	19 3	21 14	23 03	0 56	2 48	4 52	6 56	9 00	10 55	12 43	14 41	16 46
6	19 8	21 18	23 07	1 00	2 52	4 56	7 00	9 04	10 59	12 47	14 45	16 51
7	19 12	21 22	23 10	1 04	2 56	5 00	7 04	9 08	11 02	12 51	14 49	16 55
8	19 16	21 26	23 14	1 07	3 00	5 04	7 09	9 12	11 06	12 54	14 53	16 59
9	19 21	21 30	23 18	1 11	3 04	5 08	7 13	9 15	11 10	12 58	14 57	17 04
10	19 25	21 34	23 21	1 15	3 08	5 13	7 17	9 19	11 13	13 02	15 01	17 08
11	19 29	21 38	23 25	1 18	3 11	5 17	7 21	9 23	11 17	13 05	15 05	17 13
12	19 34	21 42	23 29	1 22	3 15	5 21	7 25	9 27	11 20.	13 09	15 09	17 17
13	19 38	21 46	23 33	1 26	3 19	5 25	7 29	9 31	11 24	13 13	15 13	17 21
14	19 42	21 50	23 36	1 29	3 23	5 29	7 33	9 34	11 28	13 16	15 17	17 26
15	19 47	21 54	23 40	1 33	3 27	5 33	7 37	9 38	11 31	13 20	15 21	17 30
16	19 51	21 58	23 43	1 37	3 31	5 37	7 41	9 42	11 35	13 24	15 25	17 35
17	19 55	22 02	23 47	1 40	3 35	5 42	7 45	9 46	11 38	13 28	15 30	17 39
18	20 00	22 05	23 51	1 44	3 39	5 46	7 49	9 49	11 42	13 31	15 34	17 43
19	20 04	22 09	23 54	1 48	3 43	5 50	7 53	9 53	11 46	13 35	15 38	17 48
20	20 08	22 13	23 58	1 51	3 47	5 54	7 57	10 57	11 49	13 39	15 42	17 52
21	20 12	22 17	0 02	1 55	3 51	5 58	8 01	10 00	11 53	13 43	15 46	17 57
22	20 17	22 21	0 05	1 59	3 55	6 02	8 05	10 04	11 56	13 46	15 50	18 01
23	20 21	22 25	0 09	2 03	3 59	6 07	8 09	10 08	12 00	13 50	15 55	18 06
24	20 25	22 28	0 13	2 06	4 03	6 11	8 13	10 12	12 04	13 54	15 59	18 10
25	20 29	22 32	0 16	2 10	4 07	6 15	8 17	10 15	12 07	13 58	16 03	18 15
26	20 33	22 36	0 20	2 14	4 11	6 19	8 21	10 19	12 11	14 02	16 07	18 19
27	20 37	22 40	0 23	2 18	4 15	6 23	8 25	10 23	12 14	14 06	16 12	18 23
28	20 42	22 43	0 27	2 21	4 19	6 27	8 29	10 26	12 18	14 09	16 16	18 28
29	20 46	22 46	0 31	2 25	4 23	6 31	8 33	10 30	12 22	14 13	16 20	18 32
30	20 50		0 34	2 29	4 27	6 36	8 37	10 33	12 25	14 17	16 25	18 37
31	20 54		0 38		4 31		8 41	10 37		14 21		18 41

VI. Distance of the Sea Horizon, uncorrected for effects of Refraction.*

Height.	Distance.	Height.	Distance.	Height.	Distance.	Height.	Distance.	Height.	Distance.	Height.	Distance.
Feet.		Feet.		Feet.		Feet.		Feet.		Feet.	
1·1	1	390	21	1487	41	3293	61	9032	101	17608	141
3·5	2	428	22	1561	42	3513	63	9393	103	18111	143
8·0	3	468	23	1636	43	3740	65	9760	105	18622	145
14·2	4	510	24	1713	44	3974	67	10135	107	19140	147
22·1	5	550	25	1792	45	4213	69	10518	109	19664	149
31·9	6	598	26	1872	46	4461	71	10908	111	20197	151
43·3	7	645	27	1954	47	4716	73	11304	113	20736	153
56·6	8	694	28	2039	48	4976	75	11709	115	21282	155
71·7	9	744	29	2124	49	5249	77	12120	117	21836	157
88·5	10	797	30	2212	50	5524	79	12538	119	22397	159
107	11	850	31	2301	51	5808	81	12966	121	22964	161
127	12	906	32	2393	52	6098	83	13397	123	23540	163
149	13	964	33	2485	53	6394	85	13836	125	24121	165
173	14	1023	34	2581	54	6700	87	14282	127	24711	167
199	15	1084	35	2677	55	7012	89	14737	129	25307	169
226	16	1147	36	2775	56	7332	91	15197	131	25911	171
256	17	1211	37	2875	57	7656	93	15664	133	26521	173
287	18	1278	38	2977	58	7987	95	16139	135	27139	175
319	19	1346	39	3081	59	8330	97	16622	137	27764	177
354	20	1416	40	3186	60	8678	99	17111	139	28396	179

(*Approximately* the distance visible in miles is the square root of the height in feet, an accidental relation easy to remember.)

* The effects of refraction at low angles are very variable, but in ordinary cases, if the height of observer be supposed to be increased by one-third, the distance of the visible sea horizon will not exceed the tabular value corresponding to the revised entry. Extraordinary cases are those of mirage, &c., for which no general rule can be given.

Use of the Tables.

To find the approximate time of a star passing the meridian, subtract the sun's right ascension from the star's right ascension (increasing the star's right ascension by 24 hours if it is less than the sun's right ascension), and the remainder will be the approximate (apparent) time of the star passing the meridian.

Example 1.—At what (apparent) time will the following stars be on the meridian on May 25th.

a Lyræ.

a Orionis.

	H.	M.
Right ascension *a* Lyræ	18	33
Sun's right ascension, May 25th	4	7
Approximate time of *a* Lyræ being on the meridian	14	26

	H.	M.
Right ascension *a* Orionis	5	49
Sun's right ascension, May 25th	4	7
Approximate time of *a* Orionis being on the meridian	1	42

Example 2.—At what (apparent) time will β Orionis be on the meridian December 22nd, in lat. 40° N.?

	H.	M.
Right ascension β Orionis	5	9
Sun's right ascension is greater than star's, therefore add 24 hours	24	0
	29	0
Sun's right ascension, December 22nd	18	1
Approximate time of β Orionis being on the meridian	11	8

N.B. The altitude of any star when passing the meridian may be found by adding together the complement of the latitude of the place of observation and the declination of the star, when they are of the same name, or taking their difference when of contrary names; the altitude to be reckoned from the south point of the horizon when the latitude is north, and the contrary when south; but when the sum exceeds 90° it is to be taken from 180° and the altitude is to be reckoned from the north in north latitude, and the south in south latitude. When using the artificial horizon, the altitude to which the index of the sextant is to be set must, of course, be *double the altitude* found by this method.

To find the time of the Sun's Rising or Setting, enter Table VI. with the latitude and declination, and the tabular value will show the apparent time of the sun's setting when the latitude and declension are the same name, or of its rising when the latitude and declination are of contrary names, and this, subtracted from 12 hours, will give the apparent time of the sun's rising in the former case, and of its setting in the latter.

Double the time of rising will give the length of the night.

Double the time of setting will give the length of the day.

(*Example.*) Required the (apparent) time of the sun's rising and setting, and the length of the day and night in lat. 46° N., and the declination 18 N.

Tabular value answering to lat. 46° and decl. 18° is 7 h. 19 m. Hence in lat. N. 46°, decl. N. 18, time of sunset is 7 h. 19 m., and that of sunrise is 12 h. − 7 h. 19 m. = 4 h. 41 m.

The same is true for lat. S. 46°, decl. S. 18°.

Conversely, both for lat. N. 46°, decl. S. 18°, and for lat. S. 46°, decl. N. 18°, the time of sunrise is 7 h. 19 m., and that of sunset is 4 h. 41 m.

In the first pair of cases the length of the day is 2 × 7 h. 19 m. = 14 h. 38 m., and that of the night is 2 × 4 h. 41 m. = 9 h. 22 m.; and in the second pair, conversely, the length of the night is 14 h. 38 m., and that of the day 9 h. 32 m.

To find the time of a Star's Rising and Setting, subtract the sun's right ascension, Table V., from the star's right ascension, Table I. (increasing the star's right ascension by 24 hours if it is less than the sun's right ascension), and the remainder will be the approximate time of the star's passing the meridian, then the latitude and declination found in this table will give the time the star takes in ascending from the horizon to the meridian, and descending from the meridian to the horizon, when the latitude and declination are the same names; therefore, if these hours and minutes be subtracted from the time of its passage over the meridian, the remainder will be the apparent time of its rising; and, if added, the sum will be the time of its setting.

When the latitude and declination are of contrary names, the time found in the table will be the half of the continuance of the star under the horizon; consequently it is to be subtracted from 12 hours to give half the time of its continuance above the horizon.

(*Example.*) At what time (apparent) does the star β Leonis rise and set on May 30th in lat. 46° N.?

	H.	M.	
Star's R. A.	11	43	
Sun's R. A.	4	27	
Star's approximate meridian passage	7	16	
Time in table answering to lat. 46° N. and star's declination 15° 15′ N.	7	4	
Remainder = time of star's rising	00	12	
Sum = time of star's setting	14	20	P.M.
or	2	20	A.M.

(*Example.*) At what time (apparent) does the star α Ophiuchi rise and set on May 12th, in lat. 30 S.?

	H.	M.	
Star's R. A.	17	29	
Sun's R. A.	3	15	
Star's approximate meridian passage	14	14	
Time answering in table to 30° S. lat., and star's declination 12° 39′ N. = 6 h. 36 m. which, subtracted from 12, gives 5 h. 30 m.	5	30	
Remainder = time of star's rising	8	44	
Sum = time of star's setting	19	44	P.M.
or	7	44	A.M.

Distance of the horizon:—Table VI., giving the distance of the horizon as seen over water from different heights above it, will be found very useful both in checking exaggerated estimates of the width of lakes whose opposite shores are invisible, and also as a rude means of judging the distance of objects seen across water.

TABLES* FOR THE DETERMINATION OF HEIGHTS.

By the Temperature of Boiling Water, &c.

Enter Table I., p. 98, with the boiling-point at each of the two stations, and extract the numbers that stand opposite to them in the column headed "Altitudes, &c." The difference between these numbers gives the difference of height between the two stations, supposing the mean temperature of the intermediate air to be 32° Fahr. The correction for the temperature of the air, when it differs from this value, is given in Table II. We take the mean of the thermometers (exposed in shade) at the upper and lower stations, and we enter Table II. with that mean value, and the number that stands opposite to it, in the column headed "Multiplier," must be multiplied with the results obtained from Table I. Thus:—

At station A the boiling-point = 185°·1, tabular number = 9095
„ B „ = 210°·3, „ = 887

Approximate difference of height = 8108 feet.

To correct for temperature of intermediate air:—

At station A, temp. of air = 65° Fahr.
„ B, „ = 73° „

2) 138

69 = mean temperature of intermediate air.

* These extended Tables will give much facility to the traveller both in calculating altitudes and in checking the index error of the aneroid, by means of the boiling-point thermometer. I have computed Table I. from Tables XXVI. and II., in the hypsometric series in Guyot's collection. It did not seem worth while to correct the figures thence obtained for the slight excess of temperature, viz.: 0°·015 Fahr., of the French boiling point over that of the English. It is too small to be sensible in ordinary instruments, and it becomes totally unimportant in determining *differences* of level, or *changes* in the index error of an aneroid.—F. Galton.

In Table II. the multiplier corresponding to 69° is 1·082, and 1·082 × 8108 = 8772 (neglecting decimal fractions).

In those rare cases where greater altitudes are dealt with than are included within the limits of the table, the traveller should allow 570 feet for the difference between 185° and 184°; 572 feet for that between 184° and 183°; 574 feet for the next interval, and so on.

TABLE I.

Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.
185·0	14698	17·048	188·6	12660	18·432	192·2	10644	19·910
·1	14641	17·085	·7	12603	18·472	·3	10588	19·952
·2	14584	17·122	·8	12547	18·512	·4	10533	19·995
·3	14528	17.160	·9	12490	18·552	·5	10477	20·037
·4	14471	17·197	189·0	12434	18·592	·6	10422	20·080
·5	14414	17·235	·1	12377	18·632	·7	10366	20·123
·6	14357	17·272	·2	12321	18·672	·8	10310	20·166
·7	14300	17·310	·3	12265	18·712	·9	10255	20·208
·8	14244	17·348	·4	12209	18·753	193·0	10199	20·251
·9	14187	17·385	·5	12153	18·793	·1	10144	20·294
186·0	14130	17·423	·6	12096	18·833	·2	10088	20·338
·1	14073	17·461	·7	12040	18·874	·3	10033	20·381
·2	14017	17·499	·8	11984	18·914	·4	9978	20·424
·3	13960	17·537	·9	11928	18·955	·5	9923	20·467
·4	13903	17·575	190·0	11872	18·996	·6	9867	20·511
·5	13857	17·614	·1	11816	19·036	·7	9812	20·554
·6	13790	17·652	·2	11760	19·077	·8	9757	20·598
·7	13733	17·690	·3	11704	19·118	·9	9701	20·641
·8	13676	17·729	·4	11648	19·159	194·0	9646	20·685
·9	13620	17·767	·5	11592	19·200	·1	9591	20·729
187·0	13563	17·806	·6	11536	19·241	·2	9536	20·773
·1	13506	17·844	·7	11480	19·283	·3	9481	20·817
·2	13450	17·883	·8	11424	19·324	·4	9426	20·861
·3	13394	17·922	·9	11368	19·407	·5	9371	20·905
·4	13337	17·961	191·0	11312	19·407	·6	9315	20·949
·5	13281	18·000	·1	11257	19·448	·7	9260	20·993
·6	13224	18·039	·2	11201	19·490	·8	9205	21·038
·7	13167	18·078	·3	11146	19·532	·9	9150	21·082
·8	13111	18·117	·4	11090	19·573	195·0	9095	21·126
·9	13054	18·156	·5	11034	19·615	·1	9040	21·171
188·0	12998	18·195	·6	10978	19·657	·2	8985	21·216
·1	12942	18·235	·7	10922	19·699	·3	8930	21·260
·2	12885	18·274	·8	10867	19·741	·4	8875	21·305
·3	12829	18·314	·9	10811	19·783	·5	8820	21·350
·4	12772	18·353	192·0	10755	19·825	·6	8765	21·395
·5	12716	18·393	·1	10699	19·868	·7	8710	21·440

TABLE I.—*continued.*

Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.
195·8	8655	21·485	200·5	6095	23·697	205·2	3574	26·096
·9	8600	21·530	·6	6041	23·746	·3	3521	26·149
196·0	8545	21·576	·7	5987	23·795	·4	3468	26·202
·1	8490	21·621	·8	5933	23·845	·5	3416	26·255
·2	8435	21·666	·9	5879	23·894	·6	3363	26·309
·3	8381	21·712	201·0	5825	23·943	·7	3310	26·362
·4	8326	21·751	·1	5771	23·993	·8	3256	26·416
·5	8271	21·803	·2	5717	24·042	·9	3003	26·470
·6	8216	21·849	·3	5663	24·092	206·0	3151	26·523
·7	8161	21·895	·4	5609	24·142	·1	3098	26·577
·8	8107	21·941	·5	5556	24·191	·2	3045	26·631
·9	8052	22·987	·6	5502	24·241	·3	2992	26·685
197·0	7997	22·033	·7	5448	24·291	·4	2939	26·740
·1	7942	22·079	·8	5394	24·341	·5	2886	26·794
·2	7888	22·125	·9	5340	24·391	·6	2833	26·848
·3	7833	22·172	202·0	5286	24·442	·7	2780	26·903
·4	7779	22·218	·1	5232	24·492	·8	2727	26·957
·5	7724	22·264	·2	5178	24·542	·9	2674	27·012
·6	7669	22·311	·3	5124	24·593	207·0	2622	27·066
·7	7615	22·358	·4	5070	24·644	·1	2569	27·121
·8	7560	22·404	·5	5017	24·694	·2	2516	27·176
·9	7506	22·451	·6	4964	24·745	·3	2464	27·231
198·0	7451	22·498	·7	4910	24·796	·4	2411	27·286
·1	7397	22·545	·8	4856	24·847	·5	2358	27·341
·2	7343	22·592	·9	4802	24·898	·6	2305	27·397
·3	7289	22·639	203·0	4749	24·949	·7	2252	27·452
·4	7234	22·686	·1	4695	25·000	·8	2199	27·507
·5	7180	22·734	·2	4641	25·051	·9	2146	27·563
·6	7125	22·781	·3	4588	25·103	208·0	2094	27·618
·7	7071	22·829	·4	4535	25·154	·1	2041	27·674
·8	7016	22·876	·5	4482	25·206	·2	1989	27·730
·9	6962	22·924	·6	4428	25·257	·3	1936	27·786
199·0	6908	22·971	·7	4375	25·309	·4	1884	27·842
·1	6854	23·019	·8	4322	25·361	·5	1831	27·898
·2	6800	23·067	·9	4268	25·413	·6	1778	27·954
·3	6745	23·115	204·0	4215	25·465	·7	1726	28·011
·4	6691	23·163	·1	4161	25·517	·8	1673	28·067
·5	6637	23·211	·2	4107	25·569	·9	1621	28·123
·6	6583	23·259	·3	4053	25·621	209·0	1568	28·180
·7	6529	23·308	·4	4000	25·674	·1	1516	28·237
·8	6474	23·356	·5	3947	25·726	·2	1463	28·293
·9	6420	23·405	·6	3894	25·779	·3	1411	28·350
200·0	6366	23·453	·7	3841	25·831	·4	1358	28·407
·1	6312	23·502	·8	3788	25·884	·5	1306	28·464
·2	6258	23·550	·9	3735	25·937	·6	1254	28·521
·3	6203	23·599	205·0	3682	25·990	·7	1201	28·579
·4	6149	23·648	·1	3625	26·043	·8	1149	28·636

TABLE I.—*continued.*

Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.	Boiling point Fahr.	Altitude above level at which water boils at 212° (temp. of intermediate air being 32° F.).	Approximate corresponding height of aneroid or barometer.
209·9	1096	28·693	211·6	208	29·684	213·3	− 673	30·705
210·0	1044	28·751	·7	156	29·744	·4	− 724	30·766
·1	992	28·809	·8	104	29·803	·5	− 776	30·827
·2	939	28·866	·9	52	29·862	·6	− 828	30·888
·3	887	28·924	212·0	0	29·922	·7	− 880	30·949
·4	835	28·982	·1	− 52	29·981	·8	− 932	31·010
·5	783	29·040	·2	− 104	30·041	·9	− 983	31·071
·6	730	29·098	·3	− 155	30·101	214·0	−1035	31·132
·7	678	29·156	·4	− 207	30·161	·1	−1086	31·194
·8	626	29·215	·5	− 259	30·221	·2	−1138	31·256
·9	573	29·273	·6	− 311	30·281	·3	−1189	31·318
211·0	521	29·331	·7	− 363	30·341	·4	−1241	31·380
·1	469	29·390	·8	− 414	30·401	·5	−1293	31·442
·2	417	29·449	·9	− 466	30·461	·6	−1344	31·504
·3	365	29·508	213·0	− 518	30·522	·7	−1396	31·566
·4	313	29·566	·1	− 570	30·283	·8	−1447	31·628
·5	261	29·625	·2	− 621	30·644	·9	−1549	31·690

TABLE II.—CORRECTION FOR TEMPERATURE OF INTERMEDIATE AIR.

Mean temperature of intermediate air.	Multiplier.	Mean temperature of intermediate air.	Multiplier.	Mean temperature of intermediate air.	Multiplier.	Mean temperature of intermediate air.	Multiplier.
20°	0·9974	37	1·0111	54	1·0488	70	1·0844
21	0·9976	38	1·0133	55	1·0511	71	1·0866
22	0·9978	39	1·0155	56	1·0533	72	1·0888
23	0·9981	40	1·0177	57	1·0555	73	1·0911
24	0·9983	41	1·0199	58	1·0577	74	1·0933
25	0·9985	42	1·0222	59	1·0599	75	1·0955
26	0·9987	43	1·0244	60	1·0622	76	1·0977
27	0·9989	44	1·0266	61	1·0644	77	1·0999
28	0·9992	45	1·0288	62	1·0666	78	1·1022
29	0·9994	46	1·0311	63	1·0688	79	1·1044
30	0·9996	47	1·0333	64	1·0711	80	1·1066
31	0·9998	48	1·0355	65	1·0733	81	1·1088
32	1·0000	49	1·0377	66	1·0755	82	1·1011
33	1·0022	50	1·0399	67	1·0777	83	1·1033
34	1·0044	51	1·0422	68	1·0799	84	1·1055
35	1·0066	52	1·0444	69	1·0822	85	1·1077
36	1·0088	53	1·0466				

When the boiling-point at the upper station alone is observed, we have no option but to *assume* 30·00 inches, or a little less, as the average height of the barometer at the level of the sea. The altitude of the upper station is then at once approximately obtained by inspection of Table I.; correcting for assumed temperature of the air at the sea-level. The serious inaccuracy to which the above assumption may lead, and its possible prevention by repeated observations at intervals extending over a considerable period, has already been pointed out (p. 27).

By Barometer or Aneroid.

The small but complete Tables, next page, will be especially useful to those who carry a mountain barometer and are anxious to make accurate determinations, but are not furnished with larger tables. These are calculated by Loomis, and are extracted from Guyot's collection.

Part I. gives the altitude, subject to correction, for the temperature of the air, and for the other influences which are the subjects of Parts II., III. IV., and V.

Method of Computation.—(1) Take from Part I. the two numbers corresponding to the two barometric heights; (2) from their difference subtract the correction found in Part II., with the difference between the thermometers that are attached to the barometers (*Mem.* this correction is not wanted for aneroids, for their works are mechanically compensated for temperature); (3) for the temperature of the intermediate air between the two stations, multiply the nine-hundredth part of the value already obtained by the difference between the sum of the temperatures at the two stations and 64°. This correction is additive when the sum of the temperatures exceeds 64°, otherwise it is subtractive. Otherwise, what comes to the same thing, use the multiplier already given in Table II. p. 100; (4) for further precision take corrections from Parts III. and IV., also from Part V., when the lower station is so high as to bring the case within the range of that table:—

(*Example.*)

	Upper Station.	Lower Station by Sea.
	°	°
Thermometer in open air	70·3 ..	77·5
Thermometer in barometer	70·3 ..	77·5
Barometer	23·66 ..	30·046

Latitude 21°.

Part I. gives { for 30·046 inches	27649·7
Part I. gives { for 23·66 inches	21406·9
Difference	6242·8
Part II. gives for $77°·5 - 70°·3$ (= $7°·2$).. ..	−16·9
Approximate altitude	6225·9

$$\frac{6225·9}{900} + \{77°·5 + 70°·3 - 64\} = 6·918 \times 83·8 = +579·7^{*}$$

Nearly correct altitude	6805·6
Part III. gives for above altitude and latitude 21	+13·3
Part IV. gives for above altitude	+19·3
Part V. is not used in this case	0·0
Correct height above sea	6838·2 feet.

* If Table II., p. 100, had been used, we should have written—

$$\frac{77°·5 + 70°·3}{2} = 74° \text{ nearly.}$$

The corresponding multiplier is 1·0933

$1·0933 \times 6225·9 = 6806·8$

PART I.

Argument, the observed Height of the Barometer at either Station.

Inches.	Feet.	Diff.	Inches.	Feet.	Diff.	Inches.	Feet.	Diff.	Inches.	Feet.	Diff.
11.0	1396.9	236.4	16.0	11186.3	162.8	21.0	18291.0	124.1	26.0	23871.0	100.3
11.1	1633.3	234.3	16.1	11349.1	161.8	21.1	18415.1	123.6	26.1	23971.3	99.9
11.2	1867.6	232.3	16.2	11510.9	160.8	21.2	18538.7	122.9	26.2	24071.2	99.5
11.3	2099.9	230.2	16.3	11671.7	159.8	21.3	18661.6	122.4	26.3	24170.7	99.1
11.4	2330.1	228.2	16.4	11831.5	158.8	21.4	18784.0	121.8	26.4	24269.8	98.8
11.5	2558.3	226.2	16.5	11990.3	157.9	21.5	18905.8	121.2	26.5	24368.6	98.4
11.6	2784.5	224.2	16.6	12148.2	156.9	21.6	19027.0	120.7	26.6	24467.0	98.1
11.7	3008.7	222.4	16.7	12305.1	155.9	21.7	19147.7	120.1	26.7	24565.1	97.6
11.8	3231.1	220.5	16.8	12461.0	155.1	21.8	19267.8	119.6	26.8	24662.7	97.3
11.9	3451.6	218.6	16.9	12616.1	154.1	21.9	19387.4	119.0	26.9	24760.0	97.0
12.0	3670.2	216.8	17.0	12770.2	153.3	22.0	19506.4	118.5	27.0	24857.0	96.6
12.1	3887.0	215.0	17.1	12923.5	152.3	22.1	19624.9	118.0	27.1	24953.6	96.2
12.2	4102.0	213.3	17.2	13075.8	151.5	22.2	19742.9	117.4	27.2	25049.8	95.9
12.3	5315.3	211.6	17.3	13227.3	150.6	22.3	19860.3	116.9	27.3	25145.7	95.5
12.4	4526.9	209.8	17.4	13377.9	149.7	22.4	19977.2	116.4	27.4	25241.2	95.2
12.5	4736.7	208.2	17.5	13527.6	148.9	22.5	20093.6	115.8	27.5	25536.4	94.8
12.6	4944.9	206.5	17.6	13676.5	148.0	22.6	20209.4	115.4	27.6	25431.2	94.5
12.7	5151.4	205.0	17.7	13824.5	147.2	22.7	20324.8	114.8	27.7	25525.7	94.2
12.8	5356.4	203.3	17.8	13971.7	146.3	22.8	20439.6	114.4	27.8	25619.9	93.8
12.9	5559.7	201.7	17.9	14118.0	145.6	22.9	20554.0	113.8	27.9	25713.7	93.4
13.0	5761.4	200.2	18.0	14263.6	144.7	23.0	20667.8	113.3	28.0	25807.1	93.2
13.1	5961.6	198.7	18.1	14408.3	144.0	23.1	20781.1	112.9	28.1	25900.3	92.8
13.2	6160.3	197.2	18.2	14552.3	143.1	23.2	20894.0	112.4	28.2	25593.1	92.5
13.3	6357.5	195.7	18.3	14695.4	142.4	23.3	21006.4	111.9	28.3	26085.6	92.1
13.4	6553.2	194.3	18.4	14837.8	141.6	23.4	21118.3	111.4	28.4	26177.7	91.9
13.5	6747.5	192.8	18.5	14979.4	140.9	23.5	21229.7	110.9	28.5	26269.6	91.5
13.6	6940.3	191.4	18.6	15120.3	140.0	23.6	21340.6	110.5	28.6	26361.1	91.2
13.7	7131.7	190.0	18.7	15260.3	139.4	23.7	21451.1	110.0	28.7	26452.3	90.9
13.8	7321.7	188.6	18.8	15399.7	138.6	23.8	21561.1	109.5	28.8	26543.2	90.5
13.9	7510.3	187.3	18.9	15538.3	137.9	23.9	21670.6	109.1	28.9	26633.7	90.3
14.0	7697.6	186.0	19.0	15676.2	137.1	24.0	21779.7	108.7	29.0	26724.0	89.9
14.1	7883.6	184.6	19.1	15813.3	136.5	24.1	21888.4	108.2	29.1	26813.9	89.6
14.2	8068.2	183.3	19.2	15949.8	135.7	24.2	21996.6	107.7	29.2	26903.5	89.3
14.3	8251.5	182.1	19.3	16085.5	135.0	24.3	22104.3	107.3	29.3	26992.8	89.1
14.4	8433.6	180.8	19.4	16220.5	134.3	24.4	22211.6	106.8	29.4	27081.9	88.7
14.5	8614.4	179.6	19.5	16354.8	133.7	24.5	22318.4	106.4	29.5	27170.6	88.4
14.6	8794.0	178.3	19.6	16488.5	132.9	24.6	22424.8	106.0	29.6	27259.0	88.1
14.7	8972.3	177.2	19.7	16621.4	132.3	24.7	22530.8	105.6	29.7	27347.1	87.8
14.8	9149.5	176.0	19.8	16753.7	131.6	24.8	22636.4	105.1	29.8	27434.9	87.6
14.9	9325.5	174.8	19.9	16885.3	131.0	24.9	22741.5	104.8	29.9	27522.5	87.2
15.0	9500.3	173.5	20.0	17016.3	130.3	25.0	22846.3	104.3	30.0	27609.7	86.9
15.1	9673.8	172.4	20.1	17146.6	129.7	25.1	22950.6	103.8	30.1	27696.6	86.7
15.2	9846.2	171.3	20.2	17276.3	129.0	25.2	23054.4	103.5	30.2	27783.3	86.4
15.3	10017.5	170.2	20.3	17405.3	128.4	25.3	23157.9	103.1	30.3	27869.7	86.0
15.4	10187.7	169.1	20.4	17533.7	127.7	25.4	23261.0	102.6	30.4	27955.7	85.8
15.5	10356.8	168.0	20.5	17661.4	127.2	25.5	23363.6	102.3	30.5	28041.5	85.6
15.6	10524.8	167.0	20.6	17788.6	126.5	25.6	23465.9	101.8	30.6	28127.1	85.2
15.7	10691.8	165.9	20.7	17915.1	125.9	25.7	23567.7	101.5	30.7	28212.3	85.0
15.8	10857.7	164.8	20.8	18041.0	125.3	25.8	23669.2	101.1	30.8	28297.3	84.7
15.9	11022.5	163.8	20.9	18166.3	124.7	25.9	23770.3	100.7	30.9	28382.0	84.4
16.0	11186.3		21.0	18291.0		26.0	23871.0		31.0	28466.4	

PART II.

CORRECTION DUE TO T—T′, OR THE DIFFERENCE OF THE (NOT FOR THAT OF THE INTERMEDIATE AIR) TEMPERATURES OF THE BAROMETERS THEMSELVES, AT THE TWO STATIONS.

This Correction is Negative when the Temperature at the Upper Station is lowest, and vice versâ.

T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.	T—T′.	Correction.
Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.	Fahr.	Feet.
°		°		°		°		°		°	
1	2·3	14	32·8	27	63·2	40	93·6	53	124·1	66	154·5
2	4·7	15	35·1	28	65·5	41	96·0	54	126·4	67	156·8
3	7·0	16	37·5	29	67·9	42	98·3	55	128·7	68	159·2
4	9·4	17	39·8	30	70·2	43	100·7	56	131·1	69	161·5
5	11·7	18	42·1	31	72·6	44	103·0	57	133·4	70	163·9
6	14·0	19	44·5	32	74·9	45	105·3	58	135·8	71	166·2
7	16·4	20	46·8	33	77·3	46	107·7	59	138·1	72	168·6
8	18·7	21	49·2	34	79·6	47	110·0	60	140·4	73	170·9
9	21·1	22	51·5	35	81·9	48	112·4	61	142·8	74	173·3
10	23·4	23	53·8	36	84·3	49	114·7	62	145·1	75	175·6
11	25·8	24	56·2	37	86·6	50	117·0	63	147·5	76	177·9
12	28·1	25	58·5	38	89·0	51	119·4	64	149·8	77	180·3
13	30·4	26	60·9	39	91·3	52	121·7	65	152·2	78	182·6

PART III.

CORRECTION DUE TO THE CHANGE OF GRAVITY FROM THE LATITUDE OF 45° TO THE LATITUDE OF THE PLACE OF OBSERVATION.

Positive from Lat. 0° to 45°; Negative from Lat. 45° to 90°.

PART IV.

CORRECTION FOR DECREASE OF GRAVITY ON A VERTICAL.

Always Positive.

PART V.

CORRECTION DUE TO THE HEIGHT OF THE LOWER STATION.

Always Positive.

App. Alt.	Part III. Latitude. 0° / 90°	10° / 80°	20° / 70°	30° / 60°	40° / 50°	45°	Part IV. *Always Positive.*	Part V. Height of Barometer at Lower Station. 16 in.	18 in.	20 in.	22 in.	24 in.	26 in.	28 in.	App. Alt.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1000	2·6	2·5	2·0	1·3	0·5	0	2·5	1·6	1·3	1·0	0·8	0·6	0·4	0·2	1000
2000	5·3	5·0	4·1	2·6	0·9	0	5·2	3·1	2·5	2·0	1·5	1·1	0·7	0·3	2000
3000	7·9	7·5	6·1	4·0	1·4	0	7·9	4·7	3·8	3·0	2·3	1·7	1·1	0·5	3000
4000	10·6	10·0	8·1	5·3	1·8	0	10·8	6·3	5·1	4·0	3·1	2·2	1·4	0·7	4000
5000	13·2	12·4	10·1	6·6	2·3	0	13·7	7·8	6·4	5·0	3·8	2·8	1·8	0·8	5000
6000	15·9	14·9	12·2	7·9	2·8	0	16·7	9·4	7·6	6·0	4·6	3·3	2·1	1·0	6000
7000	18·5	17·4	14·2	9·3	3·2	0	19·9	11·0	8·9	7·1	5·4	3·9	2·5	1·2	7000
8000	21·2	19·9	16·2	10·6	3·7	0	23·1	12·5	10·2	8·1	6·2	4·4	2·8	1·3	8000
9000	23·8	22·4	18·3	11·9	4·1	0	26·4	14·1	11·4	9·1	6·9	5·0	3·2	1·5	9000
10000	26·5	24·9	20·3	13·2	4·6	0	29·8	15·7	12·7	10·1	7·7	5·5	3·5	1·7	10000
11000	29·1	27·4	22·3	14·6	5·1	0	33·3	17·2	14·0	11·1	8·5	6·1	3·9	1·8	11000
12000	31·8	29·9	24·4	15·9	5·5	0	36·9	18·8	15·3	12·1	9·2	6·6	4·2	2·0	12000
13000	34·4	32·4	26·4	17·2	6·0	0	40·6	20·4	16·5	13·1	10·0	7·2	4·6	2·2	13000
14000	37·1	34·9	28·4	18·5	6·4	0	44·4	21·9	17·8	14·1	10·8	7·7	4·9	2·3	14000
15000	39·7	37·3	30·4	19·9	6·9	0	48·3	23·5	19·1	15·1	11·5	8·3	5·3	2·5	15000
16000	42·4	39·8	32·5	21·2	7·4	0	52·3	25·1	20·3	16·1	12·3	8·8	5·6	2·7	16000
17000	45·0	42·3	34·5	22·5	7·8	0	56·4	26·6	21·6	17·1	13·1	9·4	6·0	2·8	17000
18000	47·7	44·8	36·5	23·8	8·3	0	60·5	28·2	22·9	18·1	13·8	9·9	6·3	3·0	18000
19000	50·3	47·3	38·6	25·2	8·7	0	64·8	29·8	24·1	19·2	14·6	10·5	6·7	3·2	19000
20000	53·0	49·8	40·6	26·5	9·2	0	69·2	31·3	25·4	20·2	15·4	11·0	7·0	3·3	20000
21000	55·6	52·3	42·6	27·8	9·7	0	73·6	32·9	26·7	21·2	16·1	11·6	7·4	3·5	21000
22000	58·3	54·8	44·7	29·1	10·1	0	78·2	34·5	28·0	22·2	16·9	12·1	7·7	3·7	22000
23000	60·9	57·3	46·7	30·5	10·6	0	82·9	36·0	29·2	23·2	17·7	12·7	8·1	3·8	23000
24000	63·6	59·8	48·7	31·8	11·0	0	87·6	37·6	30·5	24·2	18·5	13·2	8·4	4·0	24000
25000	66·2	62·2	50·7	33·1	11·5	0	92·5	39·1	31·8	25·2	19·2	13·8	8·8	4·1	25000

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