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**A treatise describing the construction, and explaining the use of new
celestial and terrestrial globes**

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London, 1769

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and charts may then be laid before him with propriety, in order to confirm him in the knowledge of the particular parts of those very parallels, of which he has already attained a general idea upon the globe.

PROBLEM LI.

To find a signal, or warning star, that shall be upon or near the meridian of an observer, at the time any known star is perpendicular to any place on its corresponding parallel.

295. Bring the given place to the graduated side of the strong brass meridian on the terrestrial globe, and it will cut the degrees of its longitude, reckoned eastward from London, upon the upper row of figures over the equator; then

Apply to the celestial globe, and set the given star under the graduated side of the strong brass meridian, which will cut the degree of its right ascension on the equinoctial.

If

If the situation of the observer is west of the given place, subtract the terrestrial longitude from the right ascension of the star; if east, add the longitude, and move the celestial globe, till the sum or residue thereof is under the graduated side of the strong brass meridian, and then that side will be directly over those stars which are upon, or have just passed, or are not quite come up, to the observer's meridian, at the moment the given star is vertical to the place proposed; either of which will correctly answer the present purpose, and become the signal or warning star; that upon its arrival on the meridian, will declare the given star to be vertical to the place assigned.

Thus let the observer be in or near London, and the bright star in Lyra, or the harp of the first magnitude be given, it is called Vega, and marked α : this star is a correspondent to the south west cape of the island of Sardinia in the Mediterranean.

The longitude of this cape from London is 9 degrees, and the right ascension of the star Vega is 277 degrees, as London is west of Sardinia; 9 degrees subtracted from 277 degrees, leaves 268 degrees of right ascension,

ascension, to which the celestial globe being set, the graduated side of the strong brass meridian will be found directly over the star γ in Draco, and also over a star of the fourth magnitude in one of the heads of Cerberus. These are eminent signals, and both upon the meridian, when at the same time the star marked θ , in the knee of Hercules, will have passed the meridian about two minutes of an hour, and the star marked P, of the fourth magnitude in the milky way, will want about two minutes of an hour of coming to it.

Hence when the star marked γ , in the head of Draco, sends forth its perpendicular rays upon the city of London, the star Vega in Lyra will also be perpendicular to the S. W. cape of the island of Sardinia. At which time an observer at London will be sensible of the distance between the zenith of the two places, and may note the bearing of Sardinia from London upon his sensible horizon, to which he may refer at any time in the day. An observer at Sardinia may note the same with respect to the distance and bearing of London from him.

To excite students who have an aspiring emulation to improve themselves in this extensive

tenfive

tenfive science of geography and astronomy, the principal requisites whereby they may acquire universal knowledge, we shall proceed to illustrate this system of the natural agreement between the celestial and terrestrial spheres, by a few interesting examples.

EXAMPLE I.

When the star marked γ in the head of Draco is perpendicular to the city of London, the twelve following stars may be seen from thence at the same time, when they will also be perpendicular to as many places upon the earth.

296. The signal or warning star is γ in the head of Draco, which comes upon the meridian with the 268th degree of right ascension; it will be vertical to the city of London two minutes of time, after the star marked k, in the milky way, near the equinox, has passed the meridian, at which time the twelve following stars will be vertical to the places they stand against.

West

West of London.

Rig ^t . Asc.		Decl. and Lat.		W. Lon.
267 $\frac{1}{2}$	Knee of Hercules	θ 37	Carthagena, Old } Spain	$0\frac{1}{2}$
267 $\frac{1}{2}$	Wrist of Hercules	ι 30 $\frac{1}{2}$	Frontiers of Mo- } rocco and Tar- } guia	$0\frac{1}{2}$
261	Rasalhagus, Ser- } pentarius	α 12 $\frac{1}{2}$	Kingdom Kom- } bergrada, Africa	7
198	Spica Virginis	α 10	Peru, South-America	70
175	Deneb Alafad, } Lyon's tail	β 16	Chapa in Mexico	93
191	Alioth, 1st in tail } Great Bear	ϵ 57	Isle Belchier, Hu- } fons Bay	77

East of London.

Rig ^t . Asc.		Decl. and Lat.		East Lon.
277	Vega, in Lyra	α 38 $\frac{1}{2}$	S. W. Cape, Isle } of Sardinia	9
295	Atair, Eagle's neck	α 8	Frontiers of Be- } nin and Nigritia, } Africa	17
290	Swan's beak, Al- } bireo	β 27 $\frac{1}{2}$	Mid. Levata in } Tagua, Africa	22
308	Deneb, Swan's } rump	α 44 $\frac{1}{2}$	Palmyra	40
343	Sheat, in Pegafus	β 27	Middle of Mogul's } Empire	75
309	Swan's So. Wing	ϵ 33 $\frac{1}{2}$	Frontiers of Tur- } key in Asia, and } Desert Arabia	41

The use of a warning star is to point out the true time of the phenomenon, which is to be first nearly found by obtaining the time of the right ascension of that star for the evening, on which the observation is intended to be made.

This table of correspondents was formed as follows :

The right ascension and declination of the stars was found in round numbers upon the celestial globe, and written in two columns, inclosing the names of the stars; the columns for the names of the correspondent places being left blank for their insertion afterwards :

Next, as the longitude on our new terrestrial globes is numbered both ways from the meridian of London, whatever the right ascension of the signal star may happen to be, that point of the celestial sphere is likewise considered to be upon the meridian of London. Therefore,

To gain the longitude in the last column of the table, if the given stars were east of the signal, the right ascension of the warning star was subtracted from the right ascension of the given star.

But

But the west longitude was obtained by subtracting the right ascension of the given stars from that of the signal.

The reverse of this example is to find, what stars will be perpendicular to any place upon the earth, a warning star being known, that shall be upon the meridian of an observer, when the stars to be sought shall be vertical to the places assigned, which the reader will easily perform from what has been already said.

When a star is known to be perpendicular to any assigned place, its correspondence to that terrestrial point may be equally affirmed, to all those who can see it at that instant from any part of the earth, or sea, they may then happen to be upon.

If an observer in Palmyra, another in the middle of the Mogul's empire, a third at Levata in Africa, and a fourth at Chapa in Mexico, should look at the star γ , in the head of Draco, the moment it is in the zenith of London, they will see its correspondence to that metropolis at one and the same instant of time; their hour only will be different according to the difference of the meridians, as those places are situated either east or west from London.

The signal or warning star to each of these places, is the perpendicularity of that star expressed in the preceding catalogue of twelve stars.

From the observation under either of these stars in the catalogue, may be seen the other twelve stars, when they are shining over the heads of the inhabitants of all the other countries therein named.

This constitutes the system of astronomical geography before spoken of. It affords us a real assistance from the heavens, whereby we not only see the marvellous distances of a multitude of celestial bodies, composing that part of the universe, which we are permitted to behold; but it also enables us to comprehend the distances and bearings of the most remote countries from that point of the earth upon which we stand.

EXAMPLE II.

297. When the bright star marked β , in the head of Castor, is upon the meridian of London with the 110th degree of right ascension, the twelve following correspondents will be vertical to the places annexed.

Westward.

Westward.

Rigt. Afc.		Dec. and Lat.		Lon. W.
14	Girdle of Andromeda, Mizar	β 34	Kichuans, Louifiana	96
18	Cassiopea's thigh	δ 59	P. Walesfort, Hud- sons Bay	92
27	Almaak, foot of Andromeda	γ 41	Twightees, S. of Lake Michigan	83
42	Shoulder of Perseus	γ 52	Ekimos between L. Otter and L. Pitetibi, North America	68
47	Algenib, Perseus's side	α 49	Cape Risher, G. St. Lawrence	63
76	Rigel, Orion's foot	β 9	Sea and Coast of Olinda	34

Eastward.

Rigt. Afc.		Dec. and Lat.		E. Lon.
132	Great Bear's foot	α 47	Middle of Hungary	22
139	Hydra's heart	α 8	Kingdom Massey, Africa	29
143	Corner of the Lyon's mouth	ϵ 25	Nahassa, in Egypt	33
149	Regulus, Lyon's heart	α 13	Abyssinia, Africa	39
176	Third in the Sq. Great Bear	γ 53	Ostiakis, S.W. part of Siberia	66
192	N. Wing of Virgo, Vindematrix	ϵ 12	Sea 2° E. of Pon- dicherry	82

These stars are visible in the months of January, February, and March.

EXAMPLE III.

298. When the bright star marked α in the ear of corn, which the Virgin holds in her hand, called Spica Virginis, is upon the meridian of London with 198 degrees of right ascension, the following twelve stars will be vertical to the several places in the following table.

Westward.

Right Asc.		Decl. and Lat.		W. Lon.
90	First star in the foot of Castor	γ 22 $\frac{1}{2}$	Isles of Tres Marias, New Spain	108
113	Head of Pollux	β 29	Sea near C. Escondid, Florida	
139	Hydra's heart	α 7 $\frac{1}{2}$	Yamari, a Branch of the Amazonian River	61
149	Regulus, Lyon's heart	α 13	Sea 12° E. of the Antilles	49
175	Lyon's tail, Alafad	β 16	Near Bonavista, C. Verd Isles	23
191	First in tail Great Bear, Alioth	ϵ 57	Western Isles of Scotland	7

Eastward.

Eastward.

Regt. Asc.		Decl. and Lat.		E. Lon.	
212	N. Hand of Bootes	1	52	S. of Berlin, in Prussia	} 14
243	Scorpion's heart	α	25	S. Coast of Madagascar	
249	In the Back of Hercules	"	39	S. East of the Caspian Sea	} 51
277	Vega, in Lyra	α	39	Coten, in Tartary	
290	Albiero, the Swan's beak	β	28	Toudfang, in Thibet Major	} 92
294	Atair, in the Eagle	α	8	Eastern Sea, or Coast of Malacca	

This phœnomenon may be seen in the months of April, May, and June.

EXAMPLE IV.

299. When the 289th degree of right ascension is upon the meridian of London, signified by one minute of an hour after the star marked δ in the southern wing of the Eagle has passed the meridian, then the twelve following places will have the annexed stars in their zenith.

R 3

Westward.

Westward.

Rigt. Asc.		Dec. and Lat.		W. Lon.
206	The star in the leg of Bootes	η 20	Sea 2° S. Cape Corrente, Cuba	83
219	Southern Scale of Libra	α 15	Collao, in Peru	70
226	Northern Scale of Libra	β 8	Amazonia, America	63
236	A star in Scorpio	π 25	Paraguay, America	53
240	Hand of Serpentarius	δ 3	N. W. part of Brazil	49
267	Knee of Hercules	θ 37	N. of St. Michael, in the Azores	22

Eastward.

Rigt. Asc.		Dec. and Lat.		E. Lon.
321	Side of Cepheus	β 70	Fro. Sea near Isle Wardus, Laponia	32
328	Shoulder of Aquarius	α 1	Between Sio and Ampaia, Zanguebar	39
331	Firt in the head of Cepheus	ϵ 56	Ruffia, 4° E. of Moscow	42
343	Markab in Pegasus	α 27	Sea Coast, in Persian Gulph	54
359	Andromeda's head	δ 27	Tala, Mogul's Empire	70
360	A star in Pegasus	γ 14	Sea near Isle Lakedinas	71

These stars may be observed in the months of July, August, and September.

EXAMPLE

EXAMPLE V.

300. When the star marked θ in the fide of the Whale is upon the meridian of London, with 18 degrees of right ascension, the twelve following stars will be in the zenith of the annexed places.

Westward.

Rigt. Asc.		Dec and Lat		W. Lon.
290	The Swan's beak	β 28	Gulph Mexico, 3 ^o S. Miffippi	88
294	First in the Swan's wing	δ 44	Lake Michigan, Canada	84
308	Deneb, in the Swan's rump	α 44	New England	70
324	Side of Cepheus	β 70	Cumberland near Baffin's Bay	57
331	Head of Cepheus	ϵ 56	N. Sea, E. of Labrador	47
341	Fomahaut, mouth of Pifces Notius	α 30	Middle of the Atlantic Ocean	37

R 4

Eastward.

Eastward.

Rig'. Asc.		Dec. and Lat.		E. Lon.
27	Almaak, foot of } Andromeda	γ 41	Sea coast of Sardinia	9
42	Shoulder of Perseus	γ 52	Brisac Luthania	24
43	Menkar, Whale's } mouth	α 3	Bake Bake, Africa	25
53	The Pleiades	23	Frontiers of Egypt } and Nubia	35
96	North foot of Pollux	γ 16	Golconda, Asia	78
112	Procyon, little Dog	α 6	Sea ^o N.W. Achem } Summatra	94

The stars in this example may be seen in the months of October, November, and December.

PROBLEM LII.

The phænomena of the harvest moon.

301. When the moon is at or near the full, about the time of an autumnal equinox, she rises nearly at the same hour for several nights together: this phænomenon is called the harvest moon.

To account for this upon the celestial globe, set the artificial sun upon the first point

point of *Libra*, where the sun must necessarily be at every autumnal equinox, and place the artificial moon upon the first point of *Aries*, where she must be, if a full moon should happen at that time.

Rectify the globe to the position of a right sphere, art. 214. which answers to the inhabitants of the equator; bring the center of the artificial sun to the western edge of the broad paper circle, and the horary index in this case being the graduated edge of the strong brass meridian, will cut the time of the sun's setting, and the moon's rising; hence it is obvious the moon will rise when the sun sets, which will be at VI o'clock, because they are both supposed to be in the celestial equator, but in opposite signs. Therefore on that day the same phenomenon will happen in all latitudes between the equator and either pole.

But as the moon's motion in her orbit, which we shall at present consider as coincident with the ecliptic, is about 13 deg. 10 min. every day, which retards her diurnal motion about 51 min. 56 sec. of time with respect to the first point of *Aries*, this daily difference as it relates to the sun is
generally

generally reckoned at 48 minutes of time, or two minutes for every hour.

Let us now enquire upon the globe, what time the moon will rise the next night after the autumnal equinox, at which time the sun will have advanced one degree in Libra, and the moon 13 deg. 10 min. in Aries, which is 12 degrees more than the sun has done in the same time: therefore place the center of the artificial sun upon the first degree of Libra, and the artificial moon on 13 deg. 10 min. of Aries, the globe being rectified as before to the position of a right sphere, bring the artificial sun under the graduated side of the strong brass meridian, and set the horary index to XII, turn the globe until the artificial sun coincides with the western side of the broad paper circle, the horary index will shew he sets that evening at VI o'clock, and the globe being turned till the artificial moon coincides with the eastern side of the broad paper circle, the horary index will shew the moon's rising that evening to be about 48 minutes past VI o'clock, with 5 degrees of amplitude northerly, as she is now entered into the northern half of the ecliptic.

Now

Now elevate the north pole of the globe to the latitude of London, every other rectification remaining the same, and bring the artificial moon to the east side of the horizon, and the horary index will point to 20 minutes past VI, her time of rising; and her amplitude at that time will be about 8 degrees, three degrees more than at the equator the same evening.

If we thus investigate the time of the moon's rising for two or three nights together before and after the autumnal full moon, it will be found nearly the same.

The reason is, that the full moons which happen at this time of the year, are ascending from the southern into the northern signs of the zodiac: whence the moon describes a parallel to the equator every night more northerly, which increases her rising amplitudes considerably, and more so as the latitude is greater, as in the present example; hence it is plain, that the nearer any celestial object is to either pole, the sooner it ascends the horizon.

Every thing remaining as before, if we elevate the north pole of the globe to $66\frac{1}{2}$ degrees, which is the latitude of the northern
polar

polar circle, and bring the artificial moon to the east side of the horizon, she will be found to rise about the same time that the sun sets the evening after the autumnal full moon, which is about VI o'clock, at which time and place her amplitude will be about 13 degrees.

In this position of the globe, if the artificial moon be removed 13 deg. 10 min. upon the ecliptic, which is her mean motion therein for one day, and so on for fourteen nights together, she will be seen to rise within the space of one hour during that time, which will be clear on observing that half the ecliptic rises at once.

It is remarkable that when the moon varies least in the time of her rising, the diurnal differences are greatest at the times of her setting.

What has been said with respect to north latitudes is equally applicable to south latitudes.

In like manner the new moons in spring rise nearly at the same hour for several nights successively, while the full moons rise later by a greater difference than at any other time of the year, because at this time

of the year the new moons are in the ascending, and the full moons in the descending signs.

This phenomenon varies in different years: the moon's orbit being inclined to the ecliptic about 5 degrees, and the line of nodes continually moving retrograde, the inclination of her orbit to the equator will be greater sometimes than at others, which prevents her hastening to the northward or descending southward in each revolution with equal pace.

PROBLEM LIII.

To find the time of the year, in which a star rises or sets cosmically or achronically.

302. The cosmical rising and setting of a star, is when a star rises with the sun, or sets at the time the sun is rising.

The achronical rising or setting of a star, is when a star rises or sets at the time the sun is setting.

Elevate the pole of the celestial globe to the latitude of the place, and bring the star

to

to the eastern edge of the broad paper circle, and observe what degree of the ecliptic rises with it, which seek in the kalendar on the broad paper circle, against which is the day of the month whereon that star rises cosmically.

Turn the globe till the star coincides with the western edge of the horizon, and that degree of the ecliptic which is cut by the eastern side, gives the day of the month when the star sets cosmically; so likewise against the degree which sets with the star you have the day of the month of its achronical setting, and if you bring it to the eastern side of the horizon, that degree of the ecliptic then cut by the western side of the broad paper circle sought in the kalendar, will shew the day of the month when the star rises achronically.

PROBLEM LIV.

To find the time of the heliacal rising and setting of a star.

303. When a star is first visible in the morning, after having been so near the sun as to be hid by the splendor of its rays, it is said to rise heliacally.

When

When a star is immerfed in the evening, or hid by the fun's rays, it is faid to fet heliacally.

Elevate the pole of the celeftial globe to the latitude of the place, bring the ftar to the eastern fide of the broad paper circle, fix the quadrant of altitude to the zenith, and apply its graduated edge to the western fide in fuch a manner that its 12th degree above the horizon may cut the ecliptic, the point oppofite to this will be 12 degrees below the broad paper circle on the eastern fide, and is the fun's place in the ecliptic at the time a ftar of the firft magnitude riles heliacally; feek this point in the kalendar, or upon the ecliptic line on the globe, againft which you will find the day of the year when that ftar riles heliacally.

To find the heliacal fetting, bring the ftar to the western fide of the horizon, and turn the quadrant of altitude on the eastern fide, till the 12th degree cuts the ecliptic; its oppofite point is the fun's place, which fought either upon the kalendar or ecliptic line, gives the day of the year when the ftar fets heliacally.

Stars

Stars of the first magnitude, according to Ptolemy, rise or set heliacally, when they are 12 degrees distant from the sun: that is, when the star is rising, the sun must be depressed in the perpendicular below the horizon 12 degrees, that the star may be far enough from the sun's rays to be seen before he rises.

Stars of the second magnitude require the sun's depression thirteen degrees, and those of the third magnitude fourteen degrees, &c.

The manazil al kamer of the Arabian astronomers, * from Ulugh Beigh, published at Oxford 1665.

304. The manazil al kamer of the Arabian astronomers, are XXVIII, they are so called, i. e. the mansions of the moon, because they observed the moon to be in or near one of these every night during her monthly course round the earth: they are these that follow, to which upon the globe the Arabian characters are affixed, but omitted here for the want of an Arabian type.

I. *Al*

* See the Rev. Mr. Costard's History of Astronomy, p. 19.

- I. *Al Sberatân*, these are the first and second stars of Aries, or the stars in the Ram's horns, marked β and γ , with I, ϵ , signifying the first mansion of the moon; which the reader will please to remember once for all.
- II. *Botein*, the stars in the Ram's belly according to Ulugh Beigh, by Bayer and on our globe ϵ and ρ .
- III. *Al Thuraiga*, the Pleiades.
- IV. *Al Debarân*, the Bull's eye.
- V. *Al Heb'a*, the three stars in the head of Orion.
- VI. *Al Hen'ab*, the star marked ξ in the left foot of Pollux.
- VII. *Al Dira*, the two bright stars, one in the head of Castor, the other in Pollux, marked α and β .
- VIII. *Al Netbrab*, the nebulae, or group of stars in Cancer, marked ϵ called by the Greeks $\varphi\alpha\lambda\mu$, i. e. Præsepe.
- IX. *Al Terphab*, the Lyon's eye marked μ .

X. *Al Geb'ha*, the star in the Lyon's mane marked ζ .

XI. *Al Zub'rah*, the stars in the Lyon's rump marked δ and θ .

XII. *Al Serphab*, the Lyon's tail marked β , called Deneb al asad.

XIII. *Al Awwa*, they are four stars in Virgo marked η δ θ γ .

XIV. *Simák al A'zal*, the Virgin's spike marked α .

XV. *Al Gaphr*, three stars in the skirt of the robe of Virgo marked ϕ ι κ .

XVI. *Al Zubàna*, that is Libra, the northern scale is called *Zubànab Al Shemali*, and is the star marked β , the southern scale marked α , is called *Zubànab al Genubi*, Shemali signifies northern, and Genubi southern, they are exactly miscalled on the common globes of modern construction.

XVII. *Al-Ichl*, these are the four stars in Scorpio marked ν β δ π .

XVIII. *Al*

XVIII. *Al Kalb*, the scorpion's heart marked α more fully. *Kalb Al Akrab*, the word *Antares*, if it is not a corruption, has no signification, and is therefore omitted.

XIX. *Al Shaulab*, the Scorpion's tail, or the star marked λ . The word *Lefath* we have omitted, being another pronunciation of *Láfab*, the true name is *Shaulab*.

XX. *Al Náaim*, these are eight stars in Sagittary, marked $\gamma \delta \epsilon \lambda \mu \sigma \phi \psi$; Ulugh Beigh makes them only three, i. e. $\gamma \sigma \psi$.

XXI. *Al Beldab*, this is that part of the Horse in Sagittary, where there are no stars drawn, and if there be any in that part of the heavens, it is thought they are only telescopic stars.

XXII. *Sad Al Dábib*, three stars in Capricorn, marked $\alpha \beta \nu$.

XXIII. *Sad Al Bula*, the star marked ν in the hand of Aquarius.

XXIV. *Sad Al Suúd*, the stars marked β and ζ in Aquarius.

XXV. *Sad Al Achbigab*, three stars in A-quarius marked γ ξ θ .

XXVI. *Al Pberg al Mubaddem*, the stars marked α and β in Pegafus.

XXVII. *Al Pberg al Muáechir*, these are two stars, one in the head of Andromeda, marked δ , the other in the wing of Pegafus, marked γ .

XXVIII. *Al Rifhá*, the star marked β in the girdle of Andromeda.

This is a division of the heavens, different from any thing the Greeks were acquainted with, and therefore was not borrowed from them.

PROBLEM LV.

To find a meridian line.

305. Bring the sun's place in the ecliptic on the celestial globe, to the graduated side of the strong brass meridian, and set the horary index to that XII, which is most elevated; turn the globe, till the star marked γ in Cassiopea's hip, is under the graduated

duated side of the strong brass meridian, with about 11 degrees of right ascension; at which time the polar star, in the extremity of the tail of the little bear, will be above the pole, and upon the meridian also. If you find in this application of the globe, that the horary index points to any hour of the day, when the globe is rectified to the latitude of your situation, turn the globe again, till the star marked ϵ , called Alioth, being the first in the tail of the great Bear, is under the graduated side of the strong brass meridian, and then the polar star will likewise be upon the meridian, with about 191 degrees of right ascension, but under the north pole, and the horary index will point out the time of the night, when this phenomenon is to happen, before which you are to have the following apparatus properly prepared, that you may be ready to attend the observation, that is, to find your meridian line.

Suspend two plumb lines, and let their weights be immersed in water, to prevent their vibrating, but in such a manner that the string of one of them may be directly between the polar star and the string of the

other

other. After this adjustment of the two strings, if they remain untouched till the next day at noon, a meridian line may be obtained at any window in the house which has a southern aspect, by suspending lines as above from the ceiling; that next the window may be fixed, but the other should be moveable in a direction nearly east and west, the weights of these ought also to be immersed in water; then, if two persons attend a little before noon on the next day, one of them at the two first plumb lines which were adjusted to the polar star, and the other at the two plumb lines in the house which are then to be adjusted, each of them holding a sheet of white paper in their hands, to receive the shadow of the two strings cast thereon by the sun; the first observer is to give a signal to the second of the instant the two shadows on his paper are united in one and the same line, at which time the sun will be precisely upon the meridian. The other observer in the house is likewise to attend with diligence, and as the sun is coming nearer and nearer to the meridian, he is constantly to remove his moveable plumb line, and keep the shadows

dows of his two strings always united in one distinct shadow, that his observation may be compleat, when his assistant gives the definitive signal.

If this be repeated four or five times, a very accurate meridian line may be obtained, and may be drawn on the window, the floor, or a pavement, by their shadow when united by the sun's rays, and the plumb lines may be occasionally suspended from two fixed hooks, when you chuse to observe the passage of the stars a-croſs the meridian.

For the use of the curious it will not be improper to observe, that the late Dr. Bradley found that the distance of the star marked α at the extremity of the tail of the little Bear, from the polar point, was 2 deg. 1 min. 39 sec. on the first day of January, A. D. 1751, old stile; at the same time its right ascension was $10^{\circ} 45' 15''$ equal to 43 min. 1 sec. of time; and as the right ascension increases 1 min. 16 sec. every ten years, its right ascension may be obtained for any succeeding year; and having the sun's right ascension in time also, subtract the last from the first; by adding 24 hours

to the right ascension of the pole star when it is less than the sun's, the remainder will be the time of the star's coming to the meridian.

Then, as before, hang up two plumb lines, between your eye and the polar star.

PROBLEM LVI.

Of the equation of time.

306. As time flows with great regularity, it is impossible to measure it accurately, and compare its several intervals with each other, but by the motion of some of the heavenly bodies, whose progress is as uniform and regular as itself.

Ancient astronomers looked upon the sun to be sufficiently regular for this purpose; but by the accurate observations of later astronomers, it is found that neither the days, nor even the hours, as measured by the sun's apparent motion, are of an equal length on two accounts.

1st, A natural or solar day of 24 hours, is that space of time the sun takes up in passing from any particular meridian to the same again; and one revolution of the earth, with

with respect to a fixed star, is performed in 23 hours, 56 minutes, 4 seconds; therefore the unequal progression of the earth through her elliptical orbit, (as she takes almost eight days more to run through the northern half of the ecliptic, than she does to pass through the southern) is the reason that the length of the day is not exactly equal to the time in which the earth performs its rotation about its axis.

2dly, From the obliquity of the ecliptic to the equator, on which last we measure time; and as equal portions of one do not correspond to equal portions of the other, the apparent motion of the sun would not be uniform; or, in other words, those points of the equator which come to the meridian, with the place of the sun on different days, would not be at equal distances from each other.

This last is easily seen upon the globe, by bringing every tenth degree of the ecliptic to the graduated side of the strong brass meridian, and you will find that each tenth degree on the equator will not come thither with it, but in the following order from ♈ to ♎, every tenth degree of the ecliptic comes

comes sooner to the strong brass meridian than their corresponding 10ths on the equator; those in the second quadrant of the ecliptic, from \ominus to \sphericalangle , come later, from \sphericalangle to \vee sooner, and from \vee to Aries later, whilst those at the beginning of each quadrant come to the meridian at the same time; therefore the sun and clock would be equal at these four times, if the sun was not longer in passing through one half of the ecliptic than the other, and the two inequalities joined together, compose that difference which is called the equation of time.

These causes are independent of each other, sometimes they agree, and at other times are contrary to one another.

The time marked out by an uniform motion, is called true time, and that shewn by the sun, is called apparent or solar time, and their difference is the equation of time.

We now proceed to shew how the terrestrial globe will represent the real phænomena relating to the earth, when actually compared with the refulgent rays emitted from the great sphere of day.

307. The meridians on our new terrestrial globes, being secondaries to the equator, are also hour circles, and are marked as such with roman figures under the equator, and at the polar circles. But observe, there is a difference in the figures placed to the same hour circle; if it cuts the IIIrd hour upon the polar circles, it will cut the IXth hour upon the equator, which is six hours later, and so of all the rest.

Through the great Pacific sea, and the intersection of Libra, is drawn a broad meridian from pole to pole, it passes through the XIIth hour upon the equator, and the VIth hour upon each of the polar circles; this hour circle is graduated into degrees and parts, and numbered from the equator towards either pole.

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There is another broad meridian passing through the Pacific sea, at the IXth hour upon the equator, and the IIIrd hour upon each polar circle; this contains only one quadrant, or 90 degrees, the numbers annexed to it begin at the northern polar circle, and end at the tropic of Capricorn.

Here we must likewise observe, there are 23 concentric circles drawn upon the terrestrial globe within the northern and southern polar circles, which for the future we shall call polar parallels; they are placed at the distance of one degree from each other, and represent the parallels of the sun's declination, but in a different manner from the 47 parallels between the tropics.

The following problems require the globe to be placed upon a plane that is level, or truly horizontal, which is easily attained, if the floor, pavement, gravel-walk in the garden, &c. should not happen to be horizontal.

A flat seasoned board, or any box which is about two feet broad, or two feet square, if the top be perfectly flat, will answer the purpose, the upper surface of either may be set truly horizontal, by the help of a pocket

pocket spirit level, or plumb rule, if you raise or depress this or that side by a wedge or two, as the spirit level shall direct; if you have a meridian line drawn on the place over which you substitute this horizontal plane, it may be readily transferred from thence to the surface just levelled; this being done, we are prepared for the solution of the following problems.

PROBLEM LVII.

To observe the sun's altitude by the terrestrial globe, when he shines bright, or when he can but just be discerned through a cloud.

308. Consider the shade of extuberancy, which is that caused by the sphericity of the globe, heretofore called the edge of the earth's enlightened disc, and there represented by the broad paper circle, but here realized by the natural light of the sun itself.

Elevate the north pole of the globe to 66 $\frac{1}{2}$ degrees, bring that meridian or hour circle,

circle, which passes through the IXth hour upon the equator, under the graduated side of the strong brass meridian, the globe being now set upon the horizontal plane; turn it about thereon, frame and all, that the shadow of the strong brass meridian may fall directly under itself, or in other words, that the shade of its graduated face may fall exactly upon the aforesaid hour circle; at that instant the shade of extuberancy will touch the true degree of the sun's altitude upon that meridian, which passes through the IXth hour upon the equator, reckoned from the polar circle, the most elevated part of which will then be in the zenith of the place where this operation is performed, and is the same whether it should happen to be either in north or south latitude.

Thus we may, in an easy and natural manner, obtain the altitude of the sun, at any time of the day, by the terrestrial globe; for it is very plain, when the sun rises, he brushes the zenith and nadir of the globe by his rays; and as he always illuminates half of it, (or a few minutes more, as his globe is considerably larger than that
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of the earth) therefore when the sun is risen a degree higher, he must necessarily illuminate a degree beyond the zenith, and so on proportionably from time to time.

But as the illuminated part is somewhat more than half, deduct 13 minutes from the shade of extuberancy, and you have the sun's altitude with tolerable exactness.

If you have any doubt how far the shade of extuberancy exactly reaches, hold a pin, or your finger, on the globe, between the sun and point in dispute, and where the shade of either is lost, will be the point sought.

When the sun does not shine bright enough to cast a shadow.

309. Turn the meridian of the globe toward the sun, as before, or direct it so that it may lie in the same plane with it, which may be done if you have but the least glimpse of the sun through a cloud; hold a string in both hands, it having first been put between the strong brass meridian and the globe: stretch it at right angles to the meridian, and apply your face near to
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the globe, moving your eye lower and lower, till you can but just see the sun: then bring the string held as before to this point upon the globe, that it may just obscure the sun from your sight, and the degree on the aforesaid hour circle, which the string then lies upon, will be the sun's altitude required, for his rays would shew the same point if he shone out bright.

Note. The moon's altitude may be observed by either of these methods, and the altitude of any star by the last of them.

PROBLEM LVIII.

To place the terrestrial globe in the sun's rays, that it may represent the natural position of the earth, either by a meridian line, or without it.

310. If you have a meridian line, set the north and south points of the broad paper circle directly over it, the north pole of the globe being elevated to the latitude of the place, and standing upon a level plane, bring the place you are in under the graduated
side

side of the strong brass meridian, then the poles and parallel circles upon the globe will, without sensible error, correspond with those in the heavens, and each point, kingdom, and state, will be turned towards the real one which it represents.

If you have no meridian line, then the day of the month being known, find the sun's declination as before instructed, which will direct you to the parallel of the day, amongst the polar parallels, reckoned from either pole towards the polar circle; which you are to remember.

Set the globe upon your horizontal plane in the sun-shine, and put it nearly north and south by the mariner's compass, it being first elevated to the latitude of the place, and the place itself brought under the graduated side of the strong brass meridian: then move the frame and globe together, till the shade of extuberancy, or term of illumination, just touches the polar parallel for the day, and the globe will be settled as before; and if accurately performed, the variation of the magnetical needle will be shewn by the degree to which it points in the compass box.

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And here observe, if the parallel for the day should not happen to fall on any one of those drawn upon the globe, you are to estimate a proportionable part between them, and reckon that, the parallel of the day. If we had drawn more, the globe would have been confused.

The reason of this operation is, that as the sun illuminates half the globe, the shade of extuberancy will constantly be 90 degrees from the point wherein the sun is vertical.

If the sun be in the equator, the shade and illumination must terminate in the poles of the world; and when he is in any other diurnal parallel, the terms of illumination must fall short of, or go beyond either pole, as many degrees as the parallel which the sun describes that day, is distant from the equator; therefore when the shade of extuberancy touches the polar parallel for the day, the artificial globe will be in the same position, with respect to the sun, as the earth really is, and will be illuminated in the same manner.

PROBLEM

PROBLEM LIX.

To find naturally the sun's declination, diurnal parallel, and his place thereon.

311. The globe being set upon an horizontal plane, and adjusted by a meridian line or otherwise, observe upon which or between which polar parallel the term of illumination falls; its distance from the pole is the degree of the sun's declination: reckon this distance from the equator among the larger parallels, and you have the parallel which the sun describes that day; upon which if you move a card, cut in the form of a double square, until its shadow falls under itself, you will obtain the very place upon that parallel over which the sun is vertical at any hour of that day, if you set the place you are in under the graduated side of the strong brass meridian.

Note, The moon's declination, diurnal parallel and place, may be found in the same manner. Likewise when the sun does not shine bright, his declination, &c. may be found by an application in the manner of problem 57.

PROBLEM LX.

To find the sun's azimuth naturally.

312. If a great circle at right angles to the horizon passes through the zenith and nadir, and also through the sun's center, its distance from the meridian in the morning or evening of any day, reckoned upon the degrees on the inner edge of the broad paper circle, will give the azimuth required.

METHOD I.

313. Elevate either pole to the position of a parallel sphere, by bringing the north pole in north latitude, and the south pole in south latitude, into the zenith of the broad paper circle, having first placed the globe upon your meridian line, or by the other method before prescribed; hold up a plumb line so that it may pass freely near the outward edge of the broad paper circle, and move it so that the shadow of the string may fall upon the elevated pole; then cast your eye immediately to its shadow on the broad paper circle, and the degree it there

there falls upon is the sun's azimuth at that time, which may be reckoned from either the south or north points of the horizon.

METHOD II.

314. If you have only a glimpse, or faint sight of the sun, the globe being adjusted as before, stand on the shady side, and hold the plumb line on that side also, and move it till it cuts the sun's center, and the elevated pole at the same time, then cast your eye towards the broad paper circle, and the degree it there cuts is the sun's azimuth, which must be reckoned from the opposite cardinal point.

PROBLEM LXI.

To shew that in some places of the earth's surface, the sun will be twice on the same azimuth in the morning, twice on the same azimuth in the afternoon; or, in other words,

315. When the declination of the sun exceeds the latitude of any place, on either