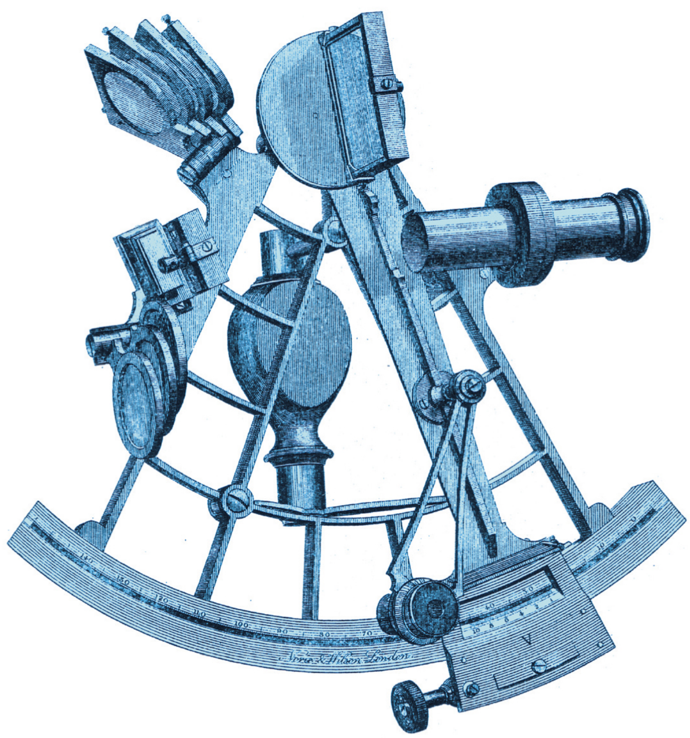
STARK TABLES

FOR

CLEARING THE LUNAR DISTANCE

AND

FINDING UNIVERSAL TIME BY SEXTANT OBSERVATION



INCLUDING
A CONVENIENT WAY TO SHARPEN
CELESTIAL NAVIGATION SKILLS WHILE ON LAND

BRUCE STARK

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Preface

These tables are the outcome of nearly two decades of experience with, and research into, the problem of getting Greenwich time from the moon. They reduce the calculation that clears a distance of refraction and parallax to a simple routine. The method fills a special niche. Unlike other easy-to-use procedures for clearing, it remains accurate when the distance is short. Short distances are the only ones the navigator of a quick-motioned small boat can hope to measure with confidence.

Lunars were more important in navigation—and for a longer period—than is commonly recognized. It is true they became really practical only in 1767, the first year of the *Nautical Almanac,* and that by then John Harrison had already perfected his best timekeeper. But special "watches" such as Harrison's were extremely difficult and expensive to build, and generations passed before they were standard equipment for ocean-going ships. On a long voyage a ship that did have a chronometer used it in conjunction with lunars.

Bowditch had more faith in lunars than in chronometers. Of longitude-by-chronometer he wrote:

> This method is useful in a short run; but in a long voyage, implicit confidence cannot be place in an instrument of such a delicate construction, and liable to so many accidents.

And of longitude-by-lunar distance:

> Other methods of finding the longitude at sea have been proposed, but among them all there is not one of such practical utility, as that by measuring the angular distance of the moon from the sun, or from certain fixed stars situated near the ecliptic, usually called a *lunar observation,* or, more frequently, *"a lunar."*

(These quotes are from the 1851 edition of *The New American Practical Navigator,* page 225. Wording is different in the 1821 edition, page 148, but the message is the same.)

Although each 0.'1 of error in the distance causes about twelve seconds of error in Greenwich time—3' of longitude—Bowditch had no trouble taking his ship from one place to another quickly and safely. He had a good idea what his maximum error in longitude could be at a given time, and allowed for it when shaping a course or making the land.

But by the middle of the nineteenth century chronometers were so reasonably priced that ships often carried three, and geography had improved to the point that almost any land raised served to check longitude. More and more steamships were being built—ships that couldn't be held up for weeks by a headwind or calm. Lunars were less and less needed. By the eighteen-nineties they were, as Captain Lecky put it in his *Wrinkles in Practical Navigation*, "... as dead as Julius Caesar."

Actually they weren't quite *that* dead. Joshua Slocum and a few others were still using them.

Now GPS is about to do for the rest of celestial navigation what chronometers and radio time signals did for the lunar. This might seem an awkward time for it, but if you enjoy using a sextant you will welcome the resurrection of the lunar distance. For one thing, lunars could help keep celestial navigation alive.

The present justification for celestial is that it provides a backup when electronics fail. The argument will have more force if lunars are part of the navigator's kit, since the electromagnetic shock wave from a nearby lightning strike can derange the timekeepers, even spring driven ones, in the same instant it takes out the electronics.

A more compelling point is this: Nothing else comes close to the lunar for developing skill with a sextant—and the observation is demanding enough to hold one's interest for a lifetime. On land a navigator who already knows his position can observe a distance on a moment's notice, day or night, without a horizon of any kind. When he compares his result with known GMT he will get the clean, reliable feedback he needs to continually improve his technique.

A third reason for resurrecting the lunar is to encourage more people to use sextants. At present it doesn't make sense to have a sextant unless you take it to sea. There's no other way to get enough satisfaction out of it to justify the price. Lunars will make land-based celestial navigation interesting enough to take up for its own sake, and amateur astronomers will find a sextant is worth owning.

The sextant doesn't belong exclusively to the sea. Explorers, geographers, and surveyors depended on sextants as they mapped the continental interiors. Not all these men are forgotten. Read a bit of history on the western two-thirds of the continent and you'll find references to Canada's intrepid David Thompson. And there are others. But of all the men who observed lunar distances on the river banks and in the mountain passes of the North American continent, the two best known—in the United States at least—are Lewis and Clark. The details of lunars are recorded in their journals.

Using the Tables

Three lunars are included as examples. One was measured from a planet, one from the sun, and one from a star. All were observed on land, but fake sea-horizon altitudes were used to clear the one on the opposite page. Height of eye is supposed to be eight feet.

Probably the quickest way to learn the method is to work the three examples for yourself. The blank forms bound into the book before the first table should be saved as patterns. Make photocopies as you need them. One form clears the distance, the other gets comparing distances (and GMT) when you have only the present-day *Nautical Almanac* to work with.

From the *Nautical Almanac:* Take the moon's H.P. for the hour you believe to be nearest the GMT of the observation. Put it in the box at the upper right corner of the form. If the distance was measured from Venus or Mars, check the bottom of page 259 in the *Almanac* to see if a value of "p." is given. If so, enter it above the moon's H.P. box. That's all you need from the *Almanac* for clearing.

To change *sextant* altitudes to apparent altitudes of the centers: If you have sextant altitudes for the moment of the distance, put them in the spaces on the top row. Circle the figure that best represents the body and limb you brought to the horizon.

There is no place on the form to adjust sextant altitudes for index and instrument error, since these are usually small, and altitudes not critical. But if combined index and instrument error amounts to 1′ or more it might be worthwhile correcting for them before putting the altitudes on the form.

Next, enter Table 1. Find your height-of-eye at the top and go down the column to the row of best fit. Take out an adjustment, together with + or - sign, for each of the altitudes. Apply these and you have **Sa** and **Ma**. Unorthodox symbols are used because, in present-day navigation, "H_a" refers to the sun's or moon's limb. These are apparent altitudes of the centers.

To change *calculated* altitudes: Since these are true altitudes you have to put parallax and refraction *into* them to get **Ma** and **Sa**. The W.W. (Wrong Way) tables give these adjustments, together with + or - signs for applying them. You will find examples on page 9, facing the W.W. Ref. Table.

Put the resulting **Sa** and **Ma** directly on the form, leaving the first two lines blank, as will be shown in the next example.

Refraction, parallax, and "Q": On the form, follow the arrow to the right of **Ma** and enter Table 2. In Table 2 the headings of both columns and rows are at 2′ intervals. That's close enough for **Ma**. Use the *nearest* value. But if there isn't an exact match for H.P. use the column headed by the next *lesser* value. Then copy increments from the table in the margin onto the next line of the form.

Move on to Table 3 and take out r&p and Q for the other body's altitude. The hundredths of a minute of arc in refraction and parallax are there so when parts are added there will be no rounding error in the tenths. The figure to the right of the comma in the Q function has a similar purpose. Don't interpolate between values. All the way through this system values are tabulated to the precision needed. Interpolation would be a waste of time. The only exception is that part of the "K" table above 104°, and it is seldom used.

Add the three lines. Q will be needed on the fourth line from the bottom. It's a negative logarithm of the ratio of cosines of true and apparent altitudes, if you are curious. But the method is designed for navigators who know nothing about trigonometry or logarithms. Those who happen to know about such

h. eye 8 ft.

	Sun / Star		Moon	
(altitude)	27° 52.5'		23° 38.0'	
Table 1	− 2.7	Table 1	+ 12.5	
Sa	27° 49.8	Ma	23° 50.5	--->
(subtract lesser)	23° 50.5	or	° .	
Ma~Sa	3° 59.3		° .	
	− 51.0		+ .	(round)
H~H	3° 8.3		° .	

from Almanac, the moon's H.P.= 56.2 (0.1)

Table 2	48.14	261.5
	1.10	6.3
Table 3	1.73	0.6
(round) ←	50.97	268.4
		Q

Table 4	15.42
SUN ? 5	.
	.
Low sun or moon? 6	− .
(round)	.

} add

	off +	on -
Index error	.	.2
Instrument	.	.
Moon's Limb Near?	.	15.4 or Far?
Ds (Sextant Distance) →	4° 19.1	15.6
	° .	
	−15.6	
Da	4° 3.5	
Ma~Sa	3° 59.3	
Da - (Ma~Sa)	0° 4.2	------> K 6.42 ¦ 8 11
Da + (Ma~Sa)	8° 2.8	------> K 2.30 ¦ 7 79

K	6.42	8 11
K	2.30	7 79
	8.73	5 9 0
half	4.36	7 9 5.0
Q		2 6 8.4
(round)	4.37	0 6 3
(subtract lesser)	3.12	5 0 2
	~~1.24~~	~~5 6 1~~

First pair } add; half and Q } add

H~H 3° 8.3	K	3.12	5 0 2
		.02	4 0 0
D 3° 13.6'	☒	3.10	1 0 2

or

date: Nov 8 '96 GMT

Previous Hour: 14

STAR: S.H.A. ° . } add
G.H.A. Aries ° .
° .
-3 6 0 ? ° .

♀

G.H.A.	66° 6.5		
G.H.A.	64° 3.0		
difference	2° 3.5	--->	K3.49 ¦ 132
Dec. (N. or (S.)?)	5° 15.7	-----> log Dec. --->	.00 ¦ 183
Dec. (N. or (S.)?)	3° 14.3	-----> log Dec. --->	. ¦ 069
difference	2° 1.4	K 3.50 ¦ 622 ←or→	3.49 ¦ 384
D	3 13.6	☒ 3.49 ¦ 384	.29 ¦ 489 (subtract lesser)
D#1	2° 52.9	~~0.01 ¦ 238~~	3.19 ¦ 895
	20.7		

date: GMT

Following Hour:

STAR: S.H.A. ° . } add
G.H.A. Aries ° .
° .
-3 6 0 ? ° .

G.H.A.	81° 6.2		
G.H.A.	78° 34.8		
difference	2° 31.4	--->	K3.31 ¦ 443
Dec. (N. or (S.)?)	5° 25.3	-----> log Dec. --->	. ¦ 195
Dec. (N. or (S)?)	3° 15.4	-----> log Dec. --->	. ¦ 670
difference	2° 9.9	K 3.44 ¦ 744 ←or→	3.31 ¦ 708
		☒ 3.31 ¦ 708	.24 ¦ 072 (subtract lesser)
D#2	3° 19.2	~~0.13 ¦ 036~~	3.07 ¦ 636
	2 52.9		
	26.3		

		Table	
D ~ D#1	20.7	7	1.0642
D#2 ~ D#1	26.3	7	−0.9603
		8	0.1039

47 min. 14 sec.

True= 47 01

error= 13

0.9603
2.4424
3.4027

0.1 Gap in context

Since they are about the same altitude, the moon and other body are affected equally by refraction. But the star or planet has little or no parallax, while the moon has a lot. She appears lower in the sky than she would otherwise. To get an idea where the *Almanac* puts the moon in relation to the star or planet, use her own diameter as a gauge. If the altitude is around 5° imagine her two diameters higher; if around 30°, one and a half diameters; around 60°, one diameter; 75°, a half.

If someone publishes an almanac, or list, of comparing distances we can look at the list to see what bodies are suitable from the *Almanac's* point of view. But whether or not an extremely short distance is also worth taking from *our* point of view will still have to be judged by eye, as that will depend on where—on the surface of the globe—we happen to be.

Another problem with short distances has to do with interpolating for GMT. In the first example—the Venus observation—the 3° 13.'6 distance got a GMT of 14:47:14. But that was based on the supposition the distance was changing at the same rate all through the hour, from 14:00 to 15:00. It wasn't. Venus was about 30° out of line with the moon's orbital motion, and alignment was changing during the hour. When a distance is that short the moon's half degree of progress along her orbit makes a difference. The amount the star or planet is out of line increases or decreases, and change in distance slows down or speeds up accordingly.

If, in the Venus example, this "second difference" in rate of change is allowed for, GMT is found to be 14:47:25. But to allow for it I had, among other things, to calculate the distance for 13:00. In my opinion second differences are not worth bothering with—not so long as we must calculate our own comparing distances, at least. The effect is greatest at the half hour, so you can limit the problem by taking your observation near the beginning or end of the hour.

Second differences were *nine times* as much of a nuisance in Bowditch's day. The maximum error they can cause is proportional to the square of the interval between comparing distances, and the interval in the *Almanac* was three hours. Consequently, distances less than 20° were seldom listed. It didn't matter then that the popular methods of clearing fell apart below 20°. When Bowditch spoke of short distances he was probably thinking of those under 50°.

Degree of fussiness: This is the measure of one's willingness to agonize over details for the sake of a little more accuracy—details such as second differences, the effect of refraction on the shape of the sun's or moon's disk (table 6), the effects of temperature and pressure on refraction, and the effects of the oblate shape of the earth on parallax and vertical plane.

No doubt there were people who took all these things into account. Certainly it would have made sense for those surveyors who provided themselves with tripods to mount their sextants or circles on. But the evidence I've come across so far suggests these details were almost universally ignored. In Bowditch's opinion it was best to skip all such embellishments and use the time saved to take observations more often.

I put table 6 in because the correction is easy to use and not apt to cause a blunder. But if the other refinements are dealt with it will be in a pamphlet, to keep them separate from these tables.

Sample Workform for Clearing the Lunar Distance

Aldeb.

° '

Table 1 .

Sa 31° 19.4

(subtract lesser) ° .

Ma~Sa ° .

− .

H~H ° .

° '

Table 1 .

Ma 57° 39.4 - - - >

or 31° 19.4

26° 20.0

+ 30.2 (round)

26° 50.2

from Almanac, the moon's H.P.= 54.6

Table 2 { 27.74 546.5

.86 17.4

Table 3 1.58 0.0

30.18 563.9

Q

Table 4 15.09 } add

SUN ? 5 .

Low sun or moon? 6 − .

(round) .

	off +	on -
Index error	.	.2
Instrument	.	.
Moon's Limb Near?	.	15.1 or Far?

Ds (Sextant Distance) → 40° 37.6 | 15.3

° .

−15.3

Da 40° 22.3

Ma~Sa 26° 20.0

Da - (Ma~Sa) 14° 2.3 - - - - - -> K 1.82 585 } add

Da + (Ma~Sa) 66° 42.3 - - - - - -> K 0.51 961

2.34 546

half 1.17 273,0 } add

Q 563,9

1.17 837 (round)

or .25 817 (subtract lesser)

0.92 020

H~H 26° 50.2 K 1.26 880

1.17 837

D 40° 34.0 0.09 043

Example of Adjusting Altitudes to an Intermediate Time

Date	May 7, 2000

Body	Sun

Elapsed Time between 1st Altitude and Time of Lunar Distance Observation

Time of 1st Altitude	23h 03m 49s			
Time of Lunar Distance Obs.	23h 08m 43s			
Difference	00h 04m 54s	Table 8	**1**	1.0894

Elapsed time Between 1st Altitude and Last Altitude

Time of 1st Altitude	23h 03m 49s			
Time of Last Altitude.	23h 12m 30s			
Difference	00h 08m 41s	Table 8	**2**	0.8395
		Subtract 2 from 1	**3**	0.2499

Change in Altitude Between 1st and Last Observation

1st Observed Altitude	42° 36.3'			
Last Observed Altitude.	41° 16.0'			
Difference	01° 20.3'	Table 7	**4**	0.4755
		Add 3 and 4,	**5**	0.7254

Enter argument 5 into **Table 7**, extract value, then add or subtract to **1st** observed altitude	00° 45.2'

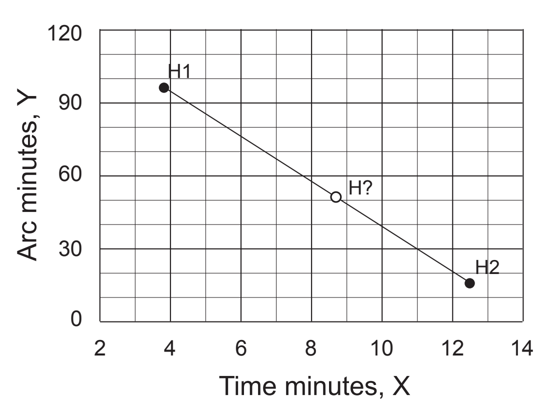
1st Observed Altitude	42° 36.3'
Increment to be Added to or Subtracted from, **1st** Altitude Observation	-00° 45.2'
Observed Altitude adjusted to common time	41° 51.1'

Courtesy of Robert Eno, Iqaluit, NT

A sun-moon lunar distance was measured at 23h 08m 43s. The sun altitude was measured first at 23h 03m 49s, which gave H1 = 42° 36.3' (plotted as 41° 96.3'), and then measured again at 23h 12m 30s, which gave H2 = 41° 16.0'.

Use the work form to find the precise value of the sun altitude (H?) at 23h 08m 43s, the time of the lunar.

In the plot:
Sight Time = 23 hr + X time min
Sextant Altitude = 41° + Y arc min



W.W.P. Moon

To get "Ma" from a CALCULATED altitude of the moon, apply this, then W.W.Ref. (Skip Table 1)

From N. Almanac	Calculated Altitude of Moon																							
	67°			68°			69°			70°			71°			72°			73°			74°		
H.P.	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'
54.0	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'9	-19.'6	-19.'3	-19.'0	-18.'7	-18.'4	-18.'1	-17.'8	-17.'5	-17.'2	-16.'9	-16.'6	-16.'3	-16.'0	-15.'7	-15.'4	-15.'1	-14.'8	-14.'5
.2	-21.'5	-21.'2	-20.'9	-20.'6	-20.'3	-20.'0	-19.'7	-19.'4	-19.'1	-18.'8	-18.'5	-18.'2	-17.'9	-17.'6	-17.'3	-17.'0	-16.'7	-16.'4	-16.'1	-15.'8	-15.'5	-15.'2	-14.'9	-14.'6
.4	-21.'6	-21.'3	-21.'0	-20.'7	-20.'4	-20.'1	-19.'8	-19.'5	-19.'2	-18.'9	-18.'6	-18.'3	-18.'0	-17.'7	-17.'4	-17.'1	-16.'8	-16.'5	-16.'1	-15.'8	-15.'5	-15.'2	-14.'9	-14.'6
.6	-21.'6	-21.'3	-21.'1	-20.'8	-20.'5	-20.'2	-19.'9	-19.'6	-19.'3	-19.'0	-18.'6	-18.'3	-18.'0	-17.'7	-17.'4	-17.'1	-16.'8	-16.'5	-16.'2	-15.'9	-15.'6	-15.'3	-15.'0	-14.'7
.8	-21.'7	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'9	-19.'6	-19.'3	-19.'0	-18.'7	-18.'4	-18.'1	-17.'8	-17.'5	-17.'2	-16.'9	-16.'6	-16.'3	-16.'0	-15.'6	-15.'3	-15.'0	-14.'7
55.0	-21.'8	-21.'5	-21.'2	-20.'9	-20.'6	-20.'3	-20.'0	-19.'7	-19.'4	-19.'1	-18.'8	-18.'5	-18.'2	-17.'9	-17.'6	-17.'3	-16.'9	-16.'6	-16.'3	-16.'0	-15.'7	-15.'4	-15.'1	-14.'8
.2	-21.'9	-21.'6	-21.'3	-21.'0	-20.'7	-20.'4	-20.'1	-19.'8	-19.'5	-19.'2	-18.'9	-18.'6	-18.'2	-17.'9	-17.'6	-17.'3	-17.'0	-16.'7	-16.'4	-16.'1	-15.'8	-15.'4	-15.'1	-14.'8
.4	-22.'0	-21.'7	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'8	-19.'5	-19.'2	-18.'9	-18.'6	-18.'3	-18.'0	-17.'7	-17.'4	-17.'1	-16.'8	-16.'4	-16.'1	-15.'8	-15.'5	-15.'2	-14.'9
.6	-22.'0	-21.'7	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'9	-19.'6	-19.'3	-19.'0	-18.'7	-18.'4	-18.'1	-17.'8	-17.'4	-17.'1	-16.'8	-16.'5	-16.'2	-15.'9	-15.'6	-15.'2	-14.'9
.8	-22.'1	-21.'8	-21.'5	-21.'2	-20.'9	-20.'6	-20.'3	-20.'0	-19.'7	-19.'4	-19.'1	-18.'8	-18.'4	-18.'1	-17.'8	-17.'5	-17.'2	-16.'9	-16.'6	-16.'3	-15.'9	-15.'6	-15.'3	-15.'0
56.0	-22.'2	-21.'9	-21.'6	-21.'3	-21.'0	-20.'7	-20.'4	-20.'1	-19.'8	-19.'4	-19.'1	-18.'8	-18.'5	-18.'2	-17.'9	-17.'6	-17.'3	-16.'9	-16.'6	-16.'3	-16.'0	-15.'7	-15.'4	-15.'0
.2	-22.'3	-22.'0	-21.'7	-21.'4	-21.'1	-20.'8	-20.'4	-20.'1	-19.'8	-19.'5	-19.'2	-18.'9	-18.'6	-18.'3	-18.'0	-17.'6	-17.'3	-17.'0	-16.'7	-16.'4	-16.'1	-15.'7	-15.'4	-15.'1
.4	-22.'4	-22.'1	-21.'8	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'9	-19.'6	-19.'3	-19.'0	-18.'6	-18.'3	-18.'0	-17.'7	-17.'4	-17.'1	-16.'7	-16.'4	-16.'1	-15.'8	-15.'5	-15.'1
.6	-22.'4	-22.'1	-21.'8	-21.'5	-21.'2	-20.'9	-20.'6	-20.'3	-20.'0	-19.'7	-19.'3	-19.'0	-18.'7	-18.'4	-18.'1	-17.'8	-17.'4	-17.'1	-16.'8	-16.'5	-16.'2	-15.'8	-15.'5	-15.'2
.8	-22.'5	-22.'2	-21.'9	-21.'6	-21.'3	-21.'0	-20.'7	-20.'4	-20.'0	-19.'7	-19.'4	-19.'1	-18.'8	-18.'5	-18.'1	-17.'8	-17.'5	-17.'2	-16.'9	-16.'5	-16.'2	-15.'9	-15.'6	-15.'3
57.0	-22.'6	-22.'3	-22.'0	-21.'7	-21.'4	-21.'1	-20.'7	-20.'4	-20.'1	-19.'8	-19.'5	-19.'2	-18.'8	-18.'5	-18.'2	-17.'9	-17.'6	-17.'3	-16.'9	-16.'6	-16.'3	-16.'0	-15.'6	-15.'3
.2	-22.'7	-22.'4	-22.'1	-21.'8	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'9	-19.'6	-19.'2	-18.'9	-18.'6	-18.'3	-18.'0	-17.'6	-17.'3	-17.'0	-16.'7	-16.'3	-16.'0	-15.'7	-15.'4
.4	-22.'8	-22.'5	-22.'1	-21.'8	-21.'5	-21.'2	-20.'9	-20.'6	-20.'3	-19.'9	-19.'6	-19.'3	-19.'0	-18.'7	-18.'3	-18.'0	-17.'7	-17.'4	-17.'0	-16.'7	-16.'4	-16.'1	-15.'7	-15.'4
.6	-22.'9	-22.'5	-22.'2	-21.'9	-21.'6	-21.'3	-21.'0	-20.'6	-20.'3	-20.'0	-19.'7	-19.'4	-19.'0	-18.'7	-18.'4	-18.'1	-17.'8	-17.'4	-17.'1	-16.'8	-16.'5	-16.'1	-15.'8	-15.'5
.8	-22.'9	-22.'6	-22.'3	-22.'0	-21.'7	-21.'4	-21.'0	-20.'7	-20.'4	-20.'1	-19.'8	-19.'4	-19.'1	-18.'8	-18.'5	-18.'1	-17.'8	-17.'5	-17.'2	-16.'8	-16.'5	-16.'2	-15.'9	-15.'5
58.0	-23.'0	-22.'7	-22.'4	-22.'1	-21.'7	-21.'4	-21.'1	-20.'8	-20.'5	-20.'2	-19.'8	-19.'5	-19.'2	-18.'9	-18.'5	-18.'2	-17.'9	-17.'6	-17.'2	-16.'9	-16.'6	-16.'2	-15.'9	-15.'6
.2	-23.'1	-22.'8	-22.'5	-22.'1	-21.'8	-21.'5	-21.'2	-20.'9	-20.'5	-20.'2	-19.'9	-19.'6	-19.'3	-18.'9	-18.'6	-18.'3	-17.'9	-17.'6	-17.'3	-17.'0	-16.'6	-16.'3	-16.'0	-15.'6
.4	-23.'2	-22.'9	-22.'5	-22.'2	-21.'9	-21.'6	-21.'3	-20.'9	-20.'6	-20.'3	-20.'0	-19.'6	-19.'3	-19.'0	-18.'7	-18.'3	-18.'0	-17.'7	-17.'4	-17.'0	-16.'7	-16.'4	-16.'0	-15.'7
.6	-23.'3	-22.'9	-22.'6	-22.'3	-22.'0	-21.'7	-21.'3	-21.'0	-20.'7	-20.'4	-20.'0	-19.'7	-19.'4	-19.'1	-18.'7	-18.'4	-18.'1	-17.'7	-17.'4	-17.'1	-16.'7	-16.'4	-16.'1	-15.'8
.8	-23.'3	-23.'0	-22.'7	-22.'4	-22.'1	-21.'7	-21.'4	-21.'1	-20.'8	-20.'4	-20.'1	-19.'8	-19.'5	-19.'1	-18.'8	-18.'5	-18.'1	-17.'8	-17.'5	-17.'1	-16.'8	-16.'5	-16.'1	-15.'8
59.0	-23.'4	-23.'1	-22.'8	-22.'5	-22.'1	-21.'8	-21.'5	-21.'2	-20.'8	-20.'5	-20.'2	-19.'8	-19.'5	-19.'2	-18.'9	-18.'5	-18.'2	-17.'9	-17.'5	-17.'2	-16.'9	-16.'5	-16.'2	-15.'9
.2	-23.'5	-23.'2	-22.'9	-22.'5	-22.'2	-21.'9	-21.'6	-21.'2	-20.'9	-20.'6	-20.'2	-19.'9	-19.'6	-19.'3	-18.'9	-18.'6	-18.'3	-17.'9	-17.'6	-17.'3	-16.'9	-16.'6	-16.'3	-15.'9
.4	-23.'6	-23.'3	-22.'9	-22.'6	-22.'3	-22.'0	-21.'6	-21.'3	-21.'0	-20.'6	-20.'3	-20.'0	-19.'7	-19.'3	-19.'0	-18.'7	-18.'3	-18.'0	-17.'7	-17.'3	-17.'0	-16.'6	-16.'3	-16.'0
.6	-23.'7	-23.'3	-23.'0	-22.'7	-22.'4	-22.'0	-21.'7	-21.'4	-21.'0	-20.'7	-20.'4	-20.'1	-19.'7	-19.'4	-19.'1	-18.'7	-18.'4	-18.'1	-17.'7	-17.'4	-17.'0	-16.'7	-16.'4	-16.'0
.8	-23.'7	-23.'4	-23.'1	-22.'8	-22.'4	-22.'1	-21.'8	-21.'4	-21.'1	-20.'8	-20.'5	-20.'1	-19.'8	-19.'5	-19.'1	-18.'8	-18.'4	-18.'1	-17.'8	-17.'4	-17.'1	-16.'8	-16.'4	-16.'1
60.0	-23.'8	-23.'5	-23.'2	-22.'8	-22.'5	-22.'2	-21.'9	-21.'5	-21.'2	-20.'9	-20.'5	-20.'2	-19.'9	-19.'5	-19.'2	-18.'8	-18.'5	-18.'2	-17.'8	-17.'5	-17.'2	-16.'8	-16.'5	-16.'1
.2	-23.'9	-23.'6	-23.'2	-22.'9	-22.'6	-22.'3	-21.'9	-21.'6	-21.'3	-20.'9	-20.'6	-20.'3	-19.'9	-19.'6	-19.'3	-18.'9	-18.'6	-18.'2	-17.'9	-17.'6	-17.'2	-16.'9	-16.'5	-16.'2
.4	-24.'0	-23.'7	-23.'3	-23.'0	-22.'7	-22.'3	-22.'0	-21.'7	-21.'3	-21.'0	-20.'7	-20.'3	-20.'0	-19.'7	-19.'3	-19.'0	-18.'6	-18.'3	-18.'0	-17.'6	-17.'3	-16.'9	-16.'6	-16.'2
.6	-24.'1	-23.'7	-23.'4	-23.'1	-22.'7	-22.'4	-22.'1	-21.'7	-21.'4	-21.'1	-20.'7	-20.'4	-20.'1	-19.'7	-19.'4	-19.'0	-18.'7	-18.'4	-18.'0	-17.'7	-17.'3	-17.'0	-16.'6	-16.'3
.8	-24.'1	-23.'8	-23.'5	-23.'1	-22.'8	-22.'5	-22.'1	-21.'8	-21.'5	-21.'1	-20.'8	-20.'5	-20.'1	-19.'8	-19.'4	-19.'1	-18.'8	-18.'4	-18.'1	-17.'7	-17.'4	-17.'0	-16.'7	-16.'4
61.0	-24.'2	-23.'9	-23.'6	-23.'2	-22.'9	-22.'6	-22.'2	-21.'9	-21.'5	-21.'2	-20.'9	-20.'5	-20.'2	-19.'9	-19.'5	-19.'2	-18.'8	-18.'5	-18.'1	-17.'8	-17.'4	-17.'1	-16.'8	-16.'4
.2	-24.'3	-24.'0	-23.'6	-23.'3	-23.'0	-22.'6	-22.'3	-22.'0	-21.'6	-21.'3	-20.'9	-20.'6	-20.'3	-19.'9	-19.'6	-19.'2	-18.'9	-18.'5	-18.'2	-17.'9	-17.'5	-17.'2	-16.'8	-16.'5
.4	-24.4	-24.'1	-23.'7	-23.'4	-23.'0	-22.'7	-22.'4	-22.'0	-21.'7	-21.'4	-21.'0	-20.'7	-20.'3	-20.'0	-19.'6	-19.'3	-19.'0	-18.'6	-18.'3	-17.'9	-17.'6	-17.'2	-16.'9	-16.'5

W.W.P. Moon

To get "Ma" from a CALCULATED altitude of the moon, apply this, then W.W.Ref. (Skip Table 1)

From N. Almanac	Calculated Altitude of Moon																				
	83°			84°			85°			86°			87°			88°			89°		
H.P.	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'	0'	20'	40'
54.0	-6.'7	-6.'4	-6.'0	-5.'7	-5.'4	-5.'1	-4.'8	-4.'5	-4.'1	-3.'8	-3.'5	-3.'2	-2.'9	-2.'6	-2.'2	-1.'9	-1.'6	-1.'3	-1.'0	-0.'6	-0.'3
55.0	-6.'8	-6.'5	-6.'2	-5.'8	-5.'5	-5.'2	-4.'9	-4.'5	-4.'2	-3.'9	-3.'6	-3.'2	-2.'9	-2.'6	-2.'3	-1.'9	-1.'6	-1.'3	-1.'0	-0.'7	-0.'3
56.0	-6.'9	-6.'6	-6.'3	-5.'9	-5.'6	-5.'3	-5.'0	-4.'6	-4.'3	-4.'0	-3.'6	-3.'3	-3.'0	-2.'6	-2.'3	-2.'0	-1.'7	-1.'3	-1.'0	-0.'7	-0.'3
57.0	-7.'1	-6.'7	-6.'4	-6.'1	-5.'7	-5.'4	-5.'0	-4.'7	-4.'4	-4.'0	-3.'7	-3.'4	-3.'0	-2.'7	-2.'4	-2.'0	-1.'7	-1.'3	-1.'0	-0.'7	-0.'3
58.0	-7.'2	-6.'8	-6.'5	-6.'2	-5.'8	-5.'5	-5.'1	-4.'8	-4.'5	-4.'1	-3.'8	-3.'4	-3.'1	-2.'7	-2.'4	-2.'1	-1.'7	-1.'4	-1.'0	-0.'7	-0.'3
59.0	-7.'3	-7.'0	-6.'6	-6.'3	-5.'9	-5.'6	-5.'2	-4.'9	-4.'5	-4.'2	-3.'8	-3.'5	-3.'1	-2.'8	-2.'4	-2.'1	-1.'7	-1.'4	-1.'0	-0.'7	-0.'3
60.0	-7.'4	-7.'1	-6.'7	-6.'4	-6.'0	-5.'7	-5.'3	-5.'0	-4.'6	-4.'3	-3.'9	-3.'5	-3.'2	-2.'8	-2.'5	-2.'1	-1.'8	-1.'4	-1.'1	-0.'7	-0.'4
61.0	-7.'6	-7.'2	-6.'8	-6.'5	-6.'1	-5.'8	-5.'4	-5.'1	-4.'7	-4.'3	-4.'0	-3.'6	-3.'2	-2.'9	-2.'5	-2.'2	-1.'8	-1.'4	-1.'1	-0.'7	-0.'4

W.W.P. **Venus** or **Mars**

Don't bother with this unless you have reason to want an unusually precise calculated apparent altitude.

If Venus or Mars has parallax (p) of 0.'1 or more any time during the year the Nautical Almanac gives it at the bottom of Page 259.

To get "Sa" from a CALCULATED Altitude of Venus or Mars apply this and W.W.Ref. (Skip Table 1)

	Calculated Altitude of Venus or Mars																
p	**5°**	**10°**	**15°**	**20°**	**25°**	**30°**	**35°**	**40°**	**45°**	**50°**	**55°**	**60°**	**65°**	**70°**	**75°**	**80°**	**85°**
0.1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	0.'0	0.'0	0.'0	0.'0	0.'0
0.2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	-0.'1	0.'0	0.'0
0.3	-0.'3	-0.'3	-0.'3	-0.'3	-0.'3	-0.'3	-0.'2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'2	-0.'1	-0.'1	-0.'1	-0.'1	0.'0
0.4	-0.'4	-0.'4	-0.'4	-0.'4	-0.'4	-0.'3	-0.'3	-0.'3	-0.'3	-0.'3	-0.'2	-0.'2	-0.'2	-0.'1	-0.'1	-0.'1	0.'0
0.5	-0.'5	-0.'5	-0.'5	-0.'5	-0.'5	-0.'4	-0.'4	-0.'4	-0.'4	-0.'3	-0.'3	-0.'3	-0.'2	-0.'2	-0.'1	-0.'1	0.'0

Changing calculated altitudes to Ma and Sa, the apparent altitudes of the centers

Sun, Star, or Planet

Calculated Altitude:	45° 31.'2
W.W. Ref. Table:	+ 0.9
Sa =	45° 32.'1

Moon

Calculated Altitude:	30° 23.8
W.W.P. Moon Table: (H.P.=57.2)	−49.7
	29 34.1
W.W. Ref. Table:	+ 1.7
Ma =	29° 35.'8

The W.W.P. Moon table has rows for H.P. as close as needed. When H.P. falls between row headings you can use *either* row. If H.P. had been 57.1 in the example you could have taken either -49.5 or -49.7 as the adjustment.

For altitudes above 9° 51 W.W. Ref. is a critical table. This means that when an altitude falls between two values in the table you should use the adjustment shown for the space between them. But when it fits one of the values in the table *exactly,* use the adjustment given for the space above. This is the same rule you use with critical tables in the front of the *Nautical Almanac.*

Add to Calculated altitude (Hc) to get Ma or Sa. For the moon, first reduce Hc with W.W.P Moon before using it to enter this table.

Hc	
4° 0'	+11.'3
4° 5'	+11.'2
4° 10'	+11.'0
4° 15'	+10.'9
4° 20'	+10.'7
4° 25'	+10.'6
4° 30'	+10.'4
4° 35'	+10.'3
4° 40'	+10.'1
4° 45'	+10.'0
4° 50'	+9.'9
4° 55'	+9.'7
5° 0'	+9.'6
5° 5'	+9.'5
5° 10'	+9.'4
5° 15'	+9.'2
5° 20'	+9.'1
5° 25'	+9.'0
5° 30'	+8.'9
5° 35'	+8.'8
5° 40'	+8.'7
5° 45'	+8.'6
5° 50'	+8.'5
5° 55'	+8.'4
6° 0'	+8.'3
6° 5'	+8.'2
6° 10'	+8.'1
6° 15'	+8.'0
6° 20'	+7.'9
6° 25'	+7.'8

Hc	
6° 30'	+7.'8
6° 35'	+7.'7
6° 40'	+7.'6
6° 45'	+7.'5
6° 50'	+7.'4
6° 55'	+7.'4
7° 0'	+7.'3
7° 5'	+7.'2
7° 10'	+7.'1
7° 15'	+7.'1
7° 20'	+7.'0
7° 25'	+6.'9
7° 30'	+6.'9
7° 35'	+6.'8
7° 40'	+6.'7
7° 45'	+6.'7
7° 50'	+6.'6
7° 55'	+6.'5
8° 0'	+6.'5
8° 10'	+6.'4
8° 20'	+6.'2
8° 30'	+6.'1
8° 40'	+6.'0
8° 50'	+5.'9
9° 0'	+5.'8
9° 10'	+5.'7
9° 20'	+5.'6
9° 30'	+5.'5
9° 40'	+5.'4
9° 50'	+5.'4

Hc	
9° 51'	
	+5.'3
10° 3'	
	+5.'2
10° 15'	
	+5.'1
10° 27'	
	+5.'0
10° 41'	
	+4.'9
10° 55'	
	+4.'8
11° 9'	
	+4.'7
11° 25'	
	+4.'6
11° 39'	
	+4.'5
11° 58'	
	+4.'4
12° 14'	
	+4.'3
12° 32'	
	+4.'2
12° 50'	
	+4.'1
13° 10'	
	+4.'0
13° 30'	
	+3.'9
13° 50'	

Hc	
13° 50'	
	+3.'8
14° 14'	
	+3.'7
14° 36'	
	+3.'6
15° 0'	
	+3.'5
15° 27'	
	+3.'4
15° 55'	
	+3.'3
16° 23'	
	+3.'2
16° 53'	
	+3.'1
17° 25'	
	+3.'0
17° 59'	
	+2.'9
18° 35'	
	+2.'8
19° 15'	
	+2.'7
19° 55'	
	+2.'6
20° 39'	
	+2.'5
21° 26'	
	+2.'4
22° 16'	

Hc	
22° 16'	
	+2.'3
23° 12'	
	+2.'2
24° 10'	
	+2.'1
25° 12'	
	+2.'0
26° 18'	
	+1.'9
27° 34'	
	+1.'8
28° 54'	
	+1.'7
30° 22'	
	+1.'6
31° 58'	
	+1.'5
33° 43'	
	+1.'4
35° 37'	
	+1.'3
37° 43'	
	+1.'2
40° 3'	
	+1.'1
42° 39'	
	+1.'0
45° 31'	
	+0.'9
48° 41'	

Hc	
48° 41'	
	+0.'8
52° 13'	
	+0.'7
56° 5'	
	+0.'6
60° 21'	
	+0.'5
65° 2'	
	+0.'4
70° 6'	
	+0.'3
75° 30'	
	+0.'2
81° 12'	
	+0.'1
87° 0'	
	+0.'0
90°	

These corrections change sextant altitudes to Sa and Ma, the apparent altitudes of the centers. For height of eye beyond the range of the table, combine the value in the zero column with dip from the *Nautical Almanac* correction table.

	Height of Eye in Feet										
	0	3	4	5	6	7	8	9	10	11	12
Sun Upper Limb April-Sept.	-15.'9	-17.'6	-17.'8	-18.'1	-18.'3	-18.'5	-18.'6	-18.'8	-19.'0	-19.'1	-19.'3
Sun Upper Limb Oct.-March	-16.'2	-17.'8	-18.'1	-18.'3	-18.'5	-18.'7	-18.'9	-19.'1	-19.'2	-19.'4	-19.'5
Sun Lower Limb April-Sept.	+15.'9	+14.'2	+13.'9	+13.'7	+13.'5	+13.'3	+13.'1	+13.'0	+12.'8	+12.'7	+12.'5
Sun Lower Limb Oct.-March	+16.'2	+14.'5	+14.'2	+14.'0	+13.'8	+13.'6	+13.'4	+13.'2	+13.'1	+12.'9	+12.'8
Star or Planet	0.'0	-1.'7	-1.'9	-2.'2	-2.'4	-2.'6	-2.'7	-2.'9	-3.'1	-3.'2	-3.'4
Moon's Upper Limb H.P.											
54.0	-14.'7	-16.'4	-16.'7	-16.'9	-17.'1	-17.'3	-17.'5	-17.'6	-17.'8	-17.'9	-18.'1
.5	-14.'9	-16.'5	-16.'8	-17.'0	-17.'2	-17.'4	-17.'6	-17.'8	-17.'9	-18.'1	-18.'2
55.0	-15.'0	-16.'7	-16.'9	-17.'2	-17.'4	-17.'6	-17.'7	-17.'9	-18.'1	-18.'2	-18.'4
.5	-15.'1	-16.'8	-17.'1	-17.'3	-17.'5	-17.'7	-17.'9	-18.'0	-18.'2	-18.'3	-18.'5
56.0	-15.'3	-16.'9	-17.'2	-17.'4	-17.'6	-17.'8	-18.'0	-18.'2	-18.'3	-18.'5	-18.'6
.5	-15.'4	-17.'1	-17.'3	-17.'6	-17.'8	-18.'0	-18.'1	-18.'3	-18.'5	-18.'6	-18.'8
57.0	-15.'5	-17.'2	-17.'5	-17.'7	-17.'9	-18.'1	-18.'3	-18.'4	-18.'6	-18.'8	-18.'9
.5	-15.'7	-17.'4	-17.'6	-17.'8	-18.'0	-18.'2	-18.'4	-18.'6	-18.'7	-18.'9	-19.'0
58.0	-15.'8	-17.'5	-17.'7	-18.'0	-18.'2	-18.'4	-18.'6	-18.'7	-18.'9	-19.'0	-19.'2
.5	-15.'9	-17.'6	-17.'9	-18.'1	-18.'3	-18.'5	-18.'7	-18.'9	-19.'0	-19.'2	-19.'3
59.0	-16.'1	-17.'8	-18.'0	-18.'3	-18.'5	-18.'6	-18.'8	-19.'0	-19.'2	-19.'3	-19.'4
.5	-16.'2	-17.'9	-18.'2	-18.'4	-18.'6	-18.'8	-19.'0	-19.'1	-19.'3	-19.'4	-19.'6
60.0	-16.'4	-18.'0	-18.'3	-18.'5	-18.'7	-18.'9	-19.'1	-19.'3	-19.'4	-19.'6	-19.'7
.5	-16.'5	-18.'2	-18.'4	-18.'7	-18.'9	-19.'1	-19.'2	-19.'4	-19.'6	-19.'7	-19.'9
61.0	-16.'6	-18.'3	-18.'6	-18.'8	-19.'0	-19.'2	-19.'4	-19.'5	-19.'7	-19.'8	-20.'0
.5	-16.'8	-18.'4	-18.'7	-18.'9	-19.'1	-19.'3	-19.'5	-19.'7	-19.'8	-20.'0	-20.'1
Moon's Lower Limb H.P.											
54.0	+14.'7	+13.'0	+12.'8	+12.'5	+12.'3	+12.'1	+12.'0	+11.'8	+11.'6	+11.'5	+11.'3
.5	+14.'9	+13.'2	+12.'9	+12.'7	+12.'5	+12.'3	+12.'1	+11.'9	+11.'8	+11.'6	+11.'5
55.0	+15.'0	+13.'3	+13.'0	+12.'8	+12.'6	+12.'4	+12.'2	+12.'1	+11.'9	+11.'8	+11.'6
.5	+15.'1	+13.'4	+13.'2	+13.'0	+12.'7	+12.'6	+12.'4	+12.'2	+12.'1	+11.'9	+11.'8
56.0	+15.'3	+13.'6	+13.'3	+13.'1	+12.'9	+12.'7	+12.'5	+12.'3	+12.'2	+12.'0	+11.'9
.5	+15.'4	+13.'7	+13.'5	+13.'2	+13.'0	+12.'8	+12.'6	+12.'5	+12.'3	+12.'2	+12.'0
57.0	+15.'5	+13.'8	+13.'6	+13.'4	+13.'2	+13.'0	+12.'8	+12.'6	+12.'5	+12.'3	+12.'2
.5	+15.'7	+14.'0	+13.'7	+13.'5	+13.'3	+13.'1	+12.'9	+12.'8	+12.'6	+12.'4	+12.'3
58.0	+15.'8	+14.'1	+13.'9	+13.'6	+13.'4	+13.'2	+13.'1	+12.'9	+12.'7	+12.'6	+12.'4
.5	+15.'9	+14.'3	+14.'0	+13.'8	+13.'6	+13.'4	+13.'2	+13.'0	+12.'9	+12.'7	+12.'6
59.0	+16.'1	+14.'4	+14.'1	+13.'9	+13.'7	+13.'5	+13.'3	+13.'2	+13.'0	+12.'9	+12.'7
.5	+16.'2	+14.'5	+14.'3	+14.'0	+13.'8	+13.'6	+13.'5	+13.'3	+13.'1	+13.'0	+12.'8
60.0	+16.'4	+14.'7	+14.'4	+14.'2	+14.'0	+13.'8	+13.'6	+13.'4	+13.'3	+13.'1	+13.'0
.5	+16.'5	+14.'8	+14.'5	+14.'3	+14.'1	+13.'9	+13.'7	+13.'6	+13.'4	+13.'3	+13.'1
61.0	+16.'6	+14.'9	+14.'7	+14.'4	+14.'2	+14.'1	+13.'9	+13.'7	+13.'5	+13.'4	+13.'3
.5	+16.'8	+15.'1	+14.'8	+14.'6	+14.'4	+14.'2	+14.'0	+13.'8	+13.'7	+13.'5	+13.'4

 Table 2

Ma		H.P.= 53' r&p	Q	H.P.= 55' r&p	Q	H.P.= 57' r&p	Q	H.P.= 59' r&p	Q	H.P.= 61' r&p	Q
4°	0'	41.'14	27,3	43.'13	29,3	45.'13	31,4	47.'12	33,5	49.'12	35,6
	2'	41.'21	27,6	43.'20	29,7	45.'20	31,8	47.'19	34,0	49.'19	36,1
	4'	41.'28	28,0	43.'27	30,1	45.'27	32,2	47.'26	34,4	49.'26	36,5
	6'	41.'35	28,4	43.'34	30,5	45.'34	32,7	47.'33	34,8	49.'33	37,0
	8'	41.'41	28,8	43.'41	30,9	45.'41	33,1	47.'40	35,2	49.'40	37,4
	10'	41.'48	29,2	43.'48	31,3	45.'47	33,5	47.'47	35,7	49.'46	37,8
	12'	41.'55	29,5	43.'54	31,7	45.'54	33,9	47.'53	36,1	49.'53	38,3
	14'	41.'62	29,9	43.'61	32,1	45.'61	34,3	47.'60	36,5	49.'60	38,7
	16'	41.'68	30,3	43.'68	32,5	45.'67	34,7	47.'67	36,9	49.'66	39,2
	18'	41.'74	30,7	43.'74	32,9	45.'73	35,1	47.'73	37,3	49.'72	39,6
	20'	41.'81	31,1	43.'80	33,3	45.'80	35,5	47.'79	37,8	49.'79	40,0
	22'	41.'87	31,4	43.'87	33,7	45.'86	35,9	47.'86	38,2	49.'85	40,5
	24'	41.'93	31,8	43.'93	34,1	45.'92	36,3	47.'92	38,6	49.'91	40,9
	26'	42.'00	32,2	43.'99	34,5	45.'98	36,8	47.'98	39,1	49.'97	41,4
	28'	42.'06	32,6	44.'05	34,9	46.'05	37,2	48.'04	39,5	50.'03	41,8
	30'	42.'12	33,0	44.'11	35,3	46.'11	37,6	48.'10	39,9	50.'09	42,2
	32'	42.'18	33,3	44.'17	35,7	46.'16	38,0	48.'16	40,3	50.'15	42,7
	34'	42.'24	33,7	44.'23	36,0	46.'22	38,4	48.'22	40,8	50.'21	43,1
	36'	42.'29	34,1	44.'29	36,4	46.'28	38,8	48.'28	41,2	50.'27	43,6
	38'	42.'35	34,5	44.'34	36,8	46.'34	39,2	48.'33	41,6	50.'33	44,0
	40'	42.'41	34,9	44.'40	37,2	46.'40	39,6	48.'39	42,0	50.'38	44,5
	42'	42.'46	35,2	44.'46	37,6	46.'45	40,0	48.'45	42,5	50.'44	44,9
	44'	42.'52	35,6	44.'51	38,0	46.'51	40,5	48.'50	42,9	50.'49	45,3
	46'	42.'58	36,0	44.'57	38,4	46.'56	40,9	48.'56	43,3	50.'55	45,8
	48'	42.'63	36,4	44.'62	38,8	46.'62	41,3	48.'61	43,7	50.'60	46,2
	50'	42.'68	36,8	44.'68	39,2	46.'67	41,7	48.'66	44,2	50.'66	46,7
	52'	42.'74	37,2	44.'73	39,6	46.'72	42,1	48.'72	44,6	50.'71	47,1
	54'	42.'79	37,5	44.'78	40,0	46.'78	42,5	48.'77	45,0	50.'76	47,6
	56'	42.'84	37,9	44.'84	40,4	46.'83	42,9	48.'82	45,5	50.'81	48,0
	58'	42.'89	38,3	44.'89	40,8	46.'88	43,3	48.'87	45,9	50.'87	48,4
5°	0'	42.'94	38,7	44.'94	41,2	46.'93	43,8	48.'92	46,3	50.'92	48,9
	2'	43.'00	39,1	44.'99	41,6	46.'98	44,2	48.'97	46,7	50.'97	49,3
	4'	43.'05	39,4	45.'04	42,0	47.'03	44,6	49.'02	47,2	51.'02	49,8
	6'	43.'09	39,8	45.'09	42,4	47.'08	45,0	49.'07	47,6	51.'07	50,2
	8'	43.'14	40,2	45.'14	42,8	47.'13	45,4	49.'12	48,0	51.'11	50,7
	10'	43.'19	40,6	45.'18	43,2	47.'18	45,8	49.'17	48,4	51.'16	51,1
	12'	43.'24	41,0	45.'23	43,6	47.'22	46,2	49.'22	48,9	51.'21	51,5
	14'	43.'29	41,4	45.'28	44,0	47.'27	46,6	49.'26	49,3	51.'26	52,0
	16'	43.'33	41,7	45.'33	44,4	47.'32	47,1	49.'31	49,7	51.'30	52,4
	18'	43.'38	42,1	45.'37	44,8	47.'36	47,5	49.'36	50,2	51.'35	52,9
	20'	43.'43	42,5	45.'42	45,2	47.'41	47,9	49.'40	50,6	51.'39	53,3
	22'	43.'47	42,9	45.'46	45,6	47.'46	48,3	49.'45	51,0	51.'44	53,8
	24'	43.'52	43,3	45.'51	46,0	47.'50	48,7	49.'49	51,4	51.'48	54,2
	26'	43.'56	43,7	45.'55	46,4	47.'55	49,1	49.'54	51,9	51.'53	54,6
	28'	43.'61	44,0	45.'60	46,8	47.'59	49,5	49.'58	52,3	51.'57	55,1
	30'	43.'65	44,4	45.'64	47,2	47.'63	50,0	49.'62	52,7	51.'61	55,5
	32'	43.'69	44,8	45.'68	47,6	47.'68	50,4	49.'67	53,2	51.'66	56,0
	34'	43.'74	45,2	45.'73	48,0	47.'72	50,8	49.'71	53,6	51.'70	56,4
	36'	43.'78	45,6	45.'77	48,4	47.'76	51,2	49.'75	54,0	51.'74	56,9
	38'	43.'82	46,0	45.'81	48,8	47.'80	51,6	49.'79	54,5	51.'78	57,3
	40'	43.'86	46,4	45.'85	49,2	47.'84	52,0	49.'83	54,9	51.'82	57,8
	42'	43.'90	46,7	45.'89	49,6	47.'88	52,4	49.'87	55,3	51.'86	58,2
	44'	43.'94	47,1	45.'93	50,0	47.'92	52,9	49.'91	55,7	51.'90	58,6
	46'	43.'98	47,5	45.'97	50,4	47.'96	53,3	49.'95	56,2	51.'94	59,1
	48'	44.'02	47,9	46.'01	50,8	48.'00	53,7	49.'99	56,6	51.'98	59,5
	50'	44.'06	48,3	46.'05	51,2	48.'04	54,1	50.'03	57,0	52.'02	60,0
	52'	44.'10	48,7	46.'09	51,6	48.'08	54,5	50.'07	57,5	52.'06	60,4
	54'	44.'14	49,0	46.'13	52,0	48.'12	54,9	50.'11	57,9	52.'10	60,9
	56'	44.'18	49,4	46.'17	52,4	48.'16	55,3	50.'15	58,3	52.'14	61,3
	58'	44.'22	49,8	46.'21	52,8	48.'20	55,8	50.'18	58,7	52.'17	61,8

4°

for H.P. increments

extra H.P.	r&p	Q
0.'1	0.'10	0,1
0.'2	0.'20	0,2
0.'3	0.'30	0,3
0.'4	0.'40	0,5
0.'5	0.'50	0,6
0.'6	0.'60	0,7
0.'7	0.'70	0,8
0.'8	0.'80	0,9
0.'9	0.'90	1,0
1.'0	1.'00	1,2
1.'1	1.'10	1,3
1.'2	1.'20	1,4
1.'3	1.'30	1,5
1.'4	1.'40	1,6
1.'5	1.'50	1,7
1.'6	1.'60	1,9
1.'7	1.'70	2,0
1.'8	1.'79	2,1
1.'9	1.'89	2,2

5°

for H.P. increments

extra H.P.	r&p	Q
0.'1	0.'10	0,1
0.'2	0.'20	0,3
0.'3	0.'30	0,4
0.'4	0.'40	0,6
0.'5	0.'50	0,7
0.'6	0.'60	0,8
0.'7	0.'70	1,0
0.'8	0.'80	1,1
0.'9	0.'90	1,2
1.'0	1.'00	1,4
1.'1	1.'10	1,5
1.'2	1.'19	1,7
1.'3	1.'29	1,8
1.'4	1.'39	1,9
1.'5	1.'49	2,1
1.'6	1.'59	2,2
1.'7	1.'69	2,4
1.'8	1.'79	2,5
1.'9	1.'89	2,6

For VENUS or MARS, check bottom of page 259 in *Nautical Almanac* for a value of "p". If none is given, use Star column.

Sa		for SUN		SATURN, JUPITER or STAR		p = 0.1		p =0.2		p =0.3		p =0.4		p =0.5		
		r&p	Q	r&p	Q	r&p	Q	r&p	Q	r&p	Q	r&p	Q	r&p	Q	
4°	0'	11.'60	2,2	11.'75	2,1	11.'65	2,2	11.'55	2,2	11.'45	2,3	11.'35	2,4	11.'25	2,5	4°
	2'	11.'53	2,2	11.'67	2,1	11.'57	2,1	11.'47	2,2	11.'37	2,3	11.'27	2,4	11.'17	2,5	
	4'	11.'45	2,2	11.'60	2,0	11.'50	2,1	11.'40	2,2	11.'30	2,3	11.'20	2,4	11.'10	2,5	
	6'	11.'38	2,1	11.'53	2,0	11.'43	2,1	11.'33	2,2	11.'23	2,3	11.'13	2,3	11.'03	2,4	
	8'	11.'31	2,1	11.'46	2,0	11.'36	2,1	11.'26	2,2	11.'16	2,2	11.'06	2,3	10.'96	2,4	
	10'	11.'24	2,1	11.'39	2,0	11.'29	2,0	11.'19	2,1	11.'09	2,2	10.'99	2,3	10.'89	2,4	
	12'	11.'17	2,1	11.'32	1,9	11.'22	2,0	11.'12	2,1	11.'02	2,2	10.'92	2,3	10.'82	2,4	
	14'	11.'11	2,0	11.'25	1,9	11.'15	2,0	11.'05	2,1	10.'95	2,2	10.'85	2,3	10.'75	2,4	
	16'	11.'04	2,0	11.'19	1,9	11.'09	2,0	10.'99	2,1	10.'89	2,2	10.'79	2,2	10.'69	2,3	
	18'	10.'97	2,0	11.'12	1,9	11.'02	2,0	10.'92	2,0	10.'82	2,1	10.'72	2,2	10.'62	2,3	
	20'	10.'91	2,0	11.'05	1,8	10.'95	1,9	10.'85	2,0	10.'75	2,1	10.'65	2,2	10.'55	2,3	
	22'	10.'84	2,0	10.'99	1,8	10.'89	1,9	10.'79	2,0	10.'69	2,1	10.'59	2,2	10.'49	2,3	
	24'	10.'78	1,9	10.'92	1,8	10.'82	1,9	10.'72	2,0	10.'62	2,1	10.'52	2,2	10.'42	2,3	
	26'	10.'71	1,9	10.'86	1,8	10.'76	1,9	10.'66	2,0	10.'56	2,1	10.'46	2,2	10.'36	2,3	
	28'	10.'65	1,9	10.'80	1,8	10.'70	1,9	10.'60	2,0	10.'50	2,0	10.'40	2,1	10.'30	2,2	
	30'	10.'59	1,9	10.'73	1,7	10.'63	1,8	10.'53	1,9	10.'43	2,0	10.'33	2,1	10.'23	2,2	
	32'	10.'52	1,9	10.'67	1,7	10.'57	1,8	10.'47	1,9	10.'37	2,0	10.'27	2,1	10.'17	2,2	
	34'	10.'46	1,8	10.'61	1,7	10.'51	1,8	10.'41	1,9	10.'31	2,0	10.'21	2,1	10.'11	2,2	
	36'	10.'40	1,8	10.'55	1,7	10.'45	1,8	10.'35	1,9	10.'25	2,0	10.'15	2,1	10.'05	2,2	
	38'	10.'34	1,8	10.'49	1,7	10.'39	1,8	10.'29	1,9	10.'19	2,0	10.'09	2,1	9.'99	2,2	
	40'	10.'28	1,8	10.'43	1,6	10.'33	1,7	10.'23	1,8	10.'13	1,9	10.'03	2,0	9.'93	2,1	
	42'	10.'22	1,8	10.'37	1,6	10.'27	1,7	10.'17	1,8	10.'07	1,9	9.'97	2,0	9.'87	2,1	
	44'	10.'17	1,8	10.'31	1,6	10.'21	1,7	10.'11	1,8	10.'01	1,9	9.'91	2,0	9.'81	2,1	
	46'	10.'11	1,7	10.'25	1,6	10.'15	1,7	10.'06	1,8	9.'96	1,9	9.'86	2,0	9.'76	2,1	
	48'	10.'05	1,7	10.'20	1,6	10.'10	1,7	10.'00	1,8	9.'90	1,9	9.'80	2,0	9.'70	2,1	
	50'	9.'99	1,7	10.'14	1,6	10.'04	1,7	9.'94	1,8	9.'84	1,9	9.'74	2,0	9.'64	2,1	
	52'	9.'94	1,7	10.'08	1,5	9.'99	1,6	9.'89	1,7	9.'79	1,9	9.'69	2,0	9.'59	2,1	
	54'	9.'88	1,7	10.'03	1,5	9.'93	1,6	9.'83	1,7	9.'73	1,8	9.'63	1,9	9.'53	2,0	
	56'	9.'83	1,7	9.'97	1,5	9.'88	1,6	9.'78	1,7	9.'68	1,8	9.'58	1,9	9.'48	2,0	
	58'	9.'77	1,6	9.'92	1,5	9.'82	1,6	9.'72	1,7	9.'62	1,8	9.'52	1,9	9.'42	2,0	
5°	0'	9.'72	1,6	9.'87	1,5	9.'77	1,6	9.'67	1,7	9.'57	1,8	9.'47	1,9	9.'37	2,0	5°
	2'	9.'67	1,6	9.'81	1,5	9.'71	1,6	9.'61	1,7	9.'51	1,8	9.'41	1,9	9.'32	2,0	
	4'	9.'61	1,6	9.'76	1,4	9.'66	1,6	9.'56	1,7	9.'46	1,8	9.'36	1,9	9.'26	2,0	
	6'	9.'56	1,6	9.'71	1,4	9.'61	1,5	9.'51	1,6	9.'41	1,8	9.'31	1,9	9.'21	2,0	
	8'	9.'51	1,6	9.'66	1,4	9.'56	1,5	9.'46	1,6	9.'36	1,7	9.'26	1,9	9.'16	2,0	
	10'	9.'46	1,6	9.'61	1,4	9.'51	1,5	9.'41	1,6	9.'31	1,7	9.'21	1,8	9.'11	2,0	
	12'	9.'41	1,5	9.'55	1,4	9.'46	1,5	9.'36	1,6	9.'26	1,7	9.'16	1,8	9.'06	1,9	
	14'	9.'36	1,5	9.'50	1,4	9.'41	1,5	9.'31	1,6	9.'21	1,7	9.'11	1,8	9.'01	1,9	
	16'	9.'31	1,5	9.'45	1,4	9.'36	1,5	9.'26	1,6	9.'16	1,7	9.'06	1,8	8.'96	1,9	
	18'	9.'26	1,5	9.'41	1,3	9.'31	1,5	9.'21	1,6	9.'11	1,7	9.'01	1,8	8.'91	1,9	
	20'	9.'21	1,5	9.'36	1,3	9.'26	1,4	9.'16	1,6	9.'06	1,7	8.'96	1,8	8.'86	1,9	
	22'	9.'16	1,5	9.'31	1,3	9.'21	1,4	9.'11	1,5	9.'01	1,7	8.'91	1,8	8.'81	1,9	
	24'	9.'11	1,5	9.'26	1,3	9.'16	1,4	9.'06	1,5	8.'96	1,6	8.'86	1,8	8.'76	1,9	
	26'	9.'07	1,5	9.'21	1,3	9.'11	1,4	9.'01	1,5	8.'91	1,6	8.'81	1,8	8.'72	1,9	
	28'	9.'02	1,4	9.'17	1,3	9.'07	1,4	8.'97	1,5	8.'87	1,6	8.'77	1,7	8.'67	1,9	

Ma

Moon's Augmented Semidiameter

H.P.	5°	10°	15°	20°	25°	30°	40°	50°	60°	90°
53.'9	14.'71	14.'73	14.'75	14.'77	14.'79	14.'80	14.'84	14.'87	14.'89	14.'92
54.'0	14.'74	14.'76	14.'78	14.'79	14.'81	14.'83	14.'87	14.'89	14.'92	14.'95
.1	14.'76	14.'78	14.'80	14.'82	14.'84	14.'86	14.'89	14.'92	14.'95	14.'98
.2	14.'79	14.'81	14.'83	14.'85	14.'87	14.'89	14.'92	14.'95	14.'97	15.'01
.3	14.'82	14.'84	14.'86	14.'88	14.'90	14.'91	14.'95	14.'98	15.'00	15.'03
.4	14.'84	14.'86	14.'88	14.'90	14.'92	14.'94	14.'98	15.'01	15.'03	15.'06
.5	14.'87	14.'89	14.'91	14.'93	14.'95	14.'97	15.'00	15.'03	15.'06	15.'09
.6	14.'90	14.'92	14.'94	14.'96	14.'98	15.'00	15.'03	15.'06	15.'09	15.'12
.7	14.'93	14.'95	14.'97	14.'99	15.'01	15.'03	15.'06	15.'09	15.'11	15.'15
.8	14.'95	14.'97	14.'99	15.'01	15.'03	15.'05	15.'09	15.'12	15.'14	15.'17
.9	14.'98	15.'00	15.'02	15.'04	15.'06	15.'08	15.'12	15.'15	15.'17	15.'20
55.'0	15.'01	15.'03	15.'05	15.'07	15.'09	15.'11	15.'14	15.'17	15.'20	15.'23
.1	15.'04	15.'06	15.'08	15.'10	15.'12	15.'14	15.'17	15.'20	15.'23	15.'26
.2	15.'06	15.'08	15.'10	15.'13	15.'14	15.'16	15.'20	15.'23	15.'25	15.'29
.3	15.'09	15.'11	15.'13	15.'15	15.'17	15.'19	15.'23	15.'26	15.'28	15.'32
.4	15.'12	15.'14	15.'16	15.'18	15.'20	15.'22	15.'25	15.'29	15.'31	15.'34
.5	15.'15	15.'17	15.'19	15.'21	15.'23	15.'25	15.'28	15.'31	15.'34	15.'37
.6	15.'17	15.'19	15.'21	15.'24	15.'26	15.'27	15.'31	15.'34	15.'37	15.'40
.7	15.'20	15.'22	15.'24	15.'26	15.'28	15.'30	15.'34	15.'37	15.'39	15.'43
.8	15.'23	15.'25	15.'27	15.'29	15.'31	15.'33	15.'37	15.'40	15.'42	15.'46
.9	15.'25	15.'28	15.'30	15.'32	15.'34	15.'36	15.'39	15.'42	15.'45	15.'48
56.'0	15.'28	15.'30	15.'32	15.'35	15.'37	15.'39	15.'42	15.'45	15.'48	15.'51
.1	15.'31	15.'33	15.'35	15.'37	15.'39	15.'41	15.'45	15.'48	15.'51	15.'54
.2	15.'34	15.'36	15.'38	15.'40	15.'42	15.'44	15.'48	15.'51	15.'53	15.'57
.3	15.'36	15.'39	15.'41	15.'43	15.'45	15.'47	15.'50	15.'54	15.'56	15.'60
.4	15.'39	15.'41	15.'43	15.'46	15.'48	15.'50	15.'53	15.'56	15.'59	15.'63
.5	15.'42	15.'44	15.'46	15.'48	15.'50	15.'52	15.'56	15.'59	15.'62	15.'65
.6	15.'45	15.'47	15.'49	15.'51	15.'53	15.'55	15.'59	15.'62	15.'65	15.'68
.7	15.'47	15.'50	15.'52	15.'54	15.'56	15.'58	15.'62	15.'65	15.'67	15.'71
.8	15.'50	15.'52	15.'54	15.'57	15.'59	15.'61	15.'64	15.'68	15.'70	15.'74
.9	15.'53	15.'55	15.'57	15.'59	15.'61	15.'63	15.'67	15.'70	15.'73	15.'77
57.'0	15.'55	15.'58	15.'60	15.'62	15.'64	15.'66	15.'70	15.'73	15.'76	15.'79
.1	15.'58	15.'60	15.'63	15.'65	15.'67	15.'69	15.'73	15.'76	15.'79	15.'82
.2	15.'61	15.'63	15.'65	15.'68	15.'70	15.'72	15.'76	15.'79	15.'81	15.'85
.3	15.'64	15.'66	15.'68	15.'70	15.'73	15.'75	15.'78	15.'82	15.'84	15.'88
.4	15.'66	15.'69	15.'71	15.'73	15.'75	15.'77	15.'81	15.'84	15.'87	15.'91
.5	15.'69	15.'71	15.'74	15.'76	15.'78	15.'80	15.'84	15.'87	15.'90	15.'94
.6	15.'72	15.'74	15.'76	15.'79	15.'81	15.'83	15.'87	15.'90	15.'93	15.'96
.7	15.'75	15.'77	15.'79	15.'81	15.'84	15.'86	15.'89	15.'93	15.'96	15.'99
.8	15.'77	15.'80	15.'82	15.'84	15.'86	15.'88	15.'92	15.'96	15.'98	16.'02
.9	15.'80	15.'82	15.'85	15.'87	15.'89	15.'91	15.'95	15.'98	16.'01	16.'05

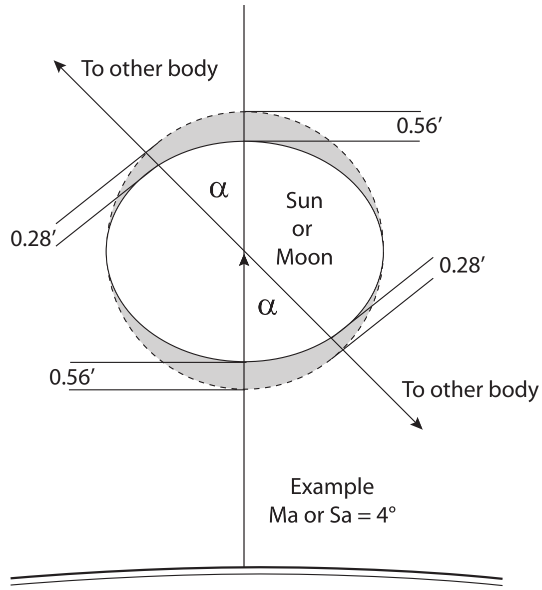
Table 5

SUN

	day of the month						
	1	5	10	15	20	25	30
				sun's semidiameter			
JAN.	16.'29	16.29	16.'29	16.'29	16.'28	16.'27	16.'26
FEB.	16.'26	16.25	16.'23	16.'22	16.'20	16.'18	
MAR.	16.'17	16.15	16.'13	16.'11	16.'09	16.'06	16.'04
APR.	16.'03	16.01	15.'99	15.'97	15.'95	15.'92	15.'90
MAY	15.'90	15.88	15.'86	15.'85	15.'83	15.'82	15.'80
JUNE	15.'80	15.79	15.'78	15.'77	15.'77	15.'76	15.'76
JULY	15.'76	15.76	15.'76	15.'76	15.'77	15.'77	15.'78
AUG.	15.'78	15.79	15.'80	15.'82	15.'83	15.'85	15.'87
SEPT.	15.'87	15.89	15.'91	15.'93	15.'95	15.'97	16.'00
OCT.	16.'00	16.02	16.'04	16.'07	16.'09	16.'11	16.'13
NOV.	16.'14	16.16	16.'18	16.'20	16.'21	16.'23	16.'24
DEC.	16.'25	16.26	16.'27	16.'28	16.'28	16.'29	16.'29

Table 6

Table 6



Angle from the Vertical (α)

Ma or Sa	0°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	70°	80°
	Apparent Reduction of Semidiameter													
4° 0'	0.'56	0.'54	0.'52	0.'49	0.'46	0.'42	0.'38	0.'33	0.'28	0.'23	0.'18	0.'14	0.'07	0.'02
4° 30'	0.'48	0.'47	0.'45	0.'42	0.'39	0.'36	0.'32	0.'28	0.'24	0.'20	0.'16	0.'12	0.'06	0.'01
5° 0'	0.'42	0.'41	0.'39	0.'37	0.'34	0.'32	0.'28	0.'25	0.'21	0.'17	0.'14	0.'11	0.'05	0.'01
5° 30'	0.'36	0.'35	0.'34	0.'32	0.'30	0.'27	0.'24	0.'21	0.'18	0.'15	0.'12	0.'09	0.'04	0.'01
6° 0'	0.'31	0.'30	0.'29	0.'27	0.'25	0.'23	0.'21	0.'18	0.'16	0.'13	0.'10	0.'08	0.'04	0.'01
6° 30'	0.'27	0.'26	0.'25	0.'24	0.'22	0.'20	0.'18	0.'16	0.'14	0.'11	0.'09	0.'07	0.'03	0.'01
7° 0'	0.'25	0.'24	0.'23	0.'22	0.'21	0.'19	0.'17	0.'15	0.'13	0.'10	0.'08	0.'06	0.'03	0.'01
7° 30'	0.'22	0.'21	0.'21	0.'19	0.'18	0.'17	0.'15	0.'13	0.'11	0.'09	0.'07	0.'06	0.'03	0.'01
8° 0'	0.'19	0.'18	0.'18	0.'17	0.'16	0.'14	0.'13	0.'11	0.'10	0.'08	0.'06	0.'05	0.'02	0.'01
9° 0'	0.'16	0.'16	0.'15	0.'14	0.'13	0.'12	0.'11	0.'09	0.'08	0.'07	0.'05	0.'04	0.'02	0.'00
10° 0'	0.'14	0.'14	0.'13	0.'12	0.'11	0.'11	0.'09	0.'08	0.'07	0.'06	0.'05	0.'04	0.'02	0.'00
11° 0'	0.'11	0.'11	0.'10	0.'10	0.'09	0.'08	0.'07	0.'06	0.'06	0.'05	0.'04	0.'03	0.'01	0.'00
13° 0'	0.'08	0.'08	0.'07	0.'07	0.'07	0.'06	0.'05	0.'05	0.'04	0.'03	0.'03	0.'02	0.'01	0.'00
15° 0'	0.'06	0.'06	0.'06	0.'05	0.'05	0.'05	0.'04	0.'04	0.'03	0.'02	0.'02	0.'02	0.'01	0.'00
20° 0'	0.'04	0.'04	0.'04	0.'04	0.'03	0.'03	0.'03	0.'02	0.'02	0.'02	0.'01	0.'01	0.'00	0.'00
30° 0'	0.'02	0.'02	0.'02	0.'02	0.'02	0.'02	0.'01	0.'01	0.'01	0.'01	0.'01	0.'01	0.'00	0.'00

	0.'0	0.'1	0.'2	0.'3	0.'4	0.'5	0.'6	0.'7	0.'8	0.'9
0'	10.2767+	9.67 461	9.07 255	8.72 037	8.47 049	8.27 667	8.11 831	7.98 441	7.86 843	7.76 612
1'	7.67 461	7.59 182	7.51 625	7.44 672	7.38 235	7.32 243	7.26 637	7.21 371	7.16 406	7.11 710
2'	7.07 255	7.03 017	6.98 976	6.95 115	6.91 419	6.87 873	6.84 466	6.81 188	6.78 029	6.74 981
3'	6.72 037	6.69 188	6.66 431	6.63 758	6.61 165	6.58 647	6.56 200	6.53 820	6.51 504	6.49 248
4'	6.47 049	6.44 904	6.42 811	6.40 767	6.38 770	6.36 818	6.34 909	6.33 041	6.31 213	6.29 422
5'	6.27 667	6.25 947	6.24 260	6.22 606	6.20 982	6.19 388	6.17 823	6.16 286	6.14 775	6.13 290
6'	6.11 831	6.10 395	6.08 982	6.07 593	6.06 225	6.04 878	6.03 552	6.02 246	6.00 959	5.99 691
7'	5.98 441	5.97 209	5.95 994	5.94 796	5.93 614	5.92 449	5.91 298	5.90 163	5.89 042	5.87 935
8'	5.86 843	5.85 764	5.84 698	5.83 645	5.82 605	5.81 577	5.80 561	5.79 557	5.78 564	5.77 583
9'	5.76 612	5.75 653	5.74 703	5.73 764	5.72 835	5.71 916	5.71 007	5.70 106	5.69 216	5.68 334
10'	5.67 461	5.66 597	5.65 741	5.64 893	5.64 054	5.63 223	5.62 400	5.61 584	5.60 776	5.59 976
11'	5.59 182	5.58 396	5.57 617	5.56 845	5.56 080	5.55 321	5.54 569	5.53 824	5.53 084	5.52 351
12'	5.51 625	5.50 904	5.50 189	5.49 480	5.48 776	5.48 079	5.47 387	5.46 700	5.46 019	5.45 343
13'	5.44 672	5.44 007	5.43 346	5.42 691	5.42 040	5.41 394	5.40 753	5.40 117	5.39 485	5.38 858
14'	5.38 235	5.37 617	5.37 003	5.36 394	5.35 788	5.35 187	5.34 590	5.33 997	5.33 408	5.32 824
15'	5.32 243	5.31 665	5.31 092	5.30 523	5.29 957	5.29 395	5.28 836	5.28 281	5.27 729	5.27 181
16'	5.26 637	5.26 096	5.25 558	5.25 023	5.24 492	5.23 964	5.23 439	5.22 918	5.22 399	5.21 884
17'	5.21 371	5.20 862	5.20 355	5.19 852	5.19 351	5.18 853	5.18 358	5.17 866	5.17 377	5.16 890
18'	5.16 406	5.15 925	5.15 447	5.14 971	5.14 497	5.14 027	5.13 558	5.13 093	5.12 629	5.12 169
19'	5.11 710	5.11 254	5.10 801	5.10 349	5.09 901	5.09 454	5.09 010	5.08 568	5.08 128	5.07 690
20'	5.07 255	5.06 822	5.06 391	5.05 962	5.05 535	5.05 110	5.04 687	5.04 267	5.03 848	5.03 432
21'	5.03 017	5.02 604	5.02 194	5.01 785	5.01 378	5.00 973	5.00 570	5.00 169	4.99 770	4.99 372
22'	4.98 976	4.98 582	4.98 190	4.97 800	4.97 411	4.97 024	4.96 639	4.96 256	4.95 874	4.95 494
23'	4.95 115	4.94 739	4.94 363	4.93 990	4.93 618	4.93 247	4.92 879	4.92 511	4.92 146	4.91 781
24'	4.91 419	4.91 058	4.90 698	4.90 340	4.89 983	4.89 628	4.89 274	4.88 922	4.88 571	4.88 221
25'	4.87 873	4.87 526	4.87 181	4.86 837	4.86 494	4.86 153	4.85 813	4.85 474	4.85 137	4.84 801
26'	4.84 466	4.84 133	4.83 801	4.83 470	4.83 140	4.82 812	4.82 485	4.82 159	4.81 834	4.81 511
27'	4.81 188	4.80 867	4.80 547	4.80 228	4.79 911	4.79 594	4.79 279	4.78 965	4.78 652	4.78 340
28'	4.78 029	4.77 720	4.77 411	4.77 104	4.76 797	4.76 492	4.76 188	4.75 885	4.75 583	4.75 281
29'	4.74 981	4.74 682	4.74 384	4.74 088	4.73 792	4.73 497	4.73 203	4.72 910	4.72 618	4.72 327
30'	4.72 037	4.71 748	4.71 460	4.71 173	4.70 886	4.70 601	4.70 317	4.70 033	4.69 751	4.69 469
31'	4.69 189	4.68 909	4.68 630	4.68 352	4.68 075	4.67 799	4.67 524	4.67 249	4.66 976	4.66 703
32'	4.66 431	4.66 160	4.65 890	4.65 621	4.65 352	4.65 084	4.64 818	4.64 552	4.64 286	4.64 022
33'	4.63 758	4.63 496	4.63 233	4.62 972	4.62 712	4.62 452	4.62 193	4.61 935	4.61 678	4.61 421
34'	4.61 165	4.60 910	4.60 656	4.60 402	4.60 149	4.59 897	4.59 646	4.59 395	4.59 145	4.58 896
35'	4.58 648	4.58 400	4.58 153	4.57 906	4.57 661	4.57 415	4.57 171	4.56 928	4.56 685	4.56 442
36'	4.56 201	4.55 960	4.55 719	4.55 480	4.55 241	4.55 003	4.54 765	4.54 528	4.54 292	4.54 056
37'	4.53 821	4.53 586	4.53 353	4.53 119	4.52 887	4.52 655	4.52 424	4.52 193	4.51 963	4.51 733
38'	4.51 504	4.51 276	4.51 049	4.50 821	4.50 595	4.50 369	4.50 144	4.49 919	4.49 695	4.49 471
39'	4.49 248	4.49 026	4.48 804	4.48 583	4.48 362	4.48 142	4.47 922	4.47 703	4.47 485	4.47 267
40'	4.47 049	4.46 832	4.46 616	4.46 400	4.46 185	4.45 970	4.45 756	4.45 542	4.45 329	4.45 117
41'	4.44 905	4.44 693	4.44 482	4.44 271	4.44 061	4.43 852	4.43 643	4.43 434	4.43 226	4.43 019
42'	4.42 811	4.42 605	4.42 399	4.42 193	4.41 988	4.41 784	4.41 579	4.41 376	4.41 173	4.40 970
43'	4.40 768	4.40 566	4.40 365	4.40 164	4.39 963	4.39 764	4.39 564	4.39 365	4.39 167	4.38 968
44'	4.38 771	4.38 574	4.38 377	4.38 181	4.37 985	4.37 789	4.37 594	4.37 400	4.37 206	4.37 012
45'	4.36 819	4.36 626	4.36 434	4.36 242	4.36 050	4.35 859	4.35 668	4.35 478	4.35 288	4.35 099
46'	4.34 910	4.34 721	4.34 533	4.34 345	4.34 158	4.33 971	4.33 784	4.33 598	4.33 412	4.33 227
47'	4.33 042	4.32 857	4.32 673	4.32 489	4.32 306	4.32 123	4.31 940	4.31 758	4.31 576	4.31 394
48'	4.31 213	4.31 032	4.30 852	4.30 672	4.30 492	4.30 313	4.30 134	4.29 956	4.29 778	4.29 600
49'	4.29 422	4.29 245	4.29 068	4.28 892	4.28 716	4.28 540	4.28 365	4.28 190	4.28 016	4.27 841
50'	4.27 668	4.27 494	4.27 321	4.27 148	4.26 975	4.26 803	4.26 631	4.26 460	4.26 289	4.26 118
51'	4.25 948	4.25 777	4.25 608	4.25 438	4.25 269	4.25 100	4.24 932	4.24 763	4.24 596	4.24 428
52'	4.24 261	4.24 094	4.23 928	4.23 761	4.23 595	4.23 430	4.23 264	4.23 100	4.22 935	4.22 770
53'	4.22 606	4.22 443	4.22 279	4.22 116	4.21 953	4.21 791	4.21 629	4.21 467	4.21 305	4.21 144
54'	4.20 983	4.20 822	4.20 662	4.20 502	4.20 342	4.20 182	4.20 023	4.19 864	4.19 706	4.19 547
55'	4.19 389	4.19 231	4.19 074	4.18 917	4.18 760	4.18 603	4.18 447	4.18 291	4.18 135	4.17 979
56'	4.17 824	4.17 669	4.17 514	4.17 360	4.17 206	4.17 052	4.16 898	4.16 745	4.16 592	4.16 439
57'	4.16 287	4.16 135	4.15 983	4.15 831	4.15 679	4.15 528	4.15 377	4.15 227	4.15 076	4.14 926
58'	4.14 776	4.14 627	4.14 477	4.14 328	4.14 179	4.14 031	4.13 882	4.13 734	4.13 586	4.13 439
59'	4.13 291	4.13 144	4.12 998	4.12 851	4.12 705	4.12 558	4.12 413	4.12 267	4.12 122	4.11 977

.05 3	.05 3	.05 2	.05 2	.05 1	.05 1	.05 0	.05 0	.04 9
0.87 824 *99*	**0.88 253** *49*	**0.88 687** *99*	**0.89 124** *49*	**0.89 565** *99*	**0.90 011** *49*	**0.90 460** *99*	**0.90 913** *49*	**0.91 371** *99*
.87 832 *98*	**.88 262** *48*	**.88 696** *98*	**.89 133** *48*	**.89 574** *98*	**.90 020** *48*	**.90 469** *98*	**.90 923** *48*	**.91 380** *98*
.87 841 *97*	**.88 271** *47*	**.88 704** *97*	**.89 142** *47*	**.89 583** *97*	**.90 028** *47*	**.90 478** *97*	**.90 932** *47*	**.91 390** *97*
.87 849 *96*	**.88 279** *46*	**.88 713** *96*	**.89 151** *46*	**.89 592** *96*	**.90 037** *46*	**.90 487** *96*	**.90 941** *46*	**.91 399** *96*
.87 858 *95*	**.88 288** *45*	**.88 722** *95*	**.89 159** *45*	**.89 601** *95*	**.90 046** *45*	**.90 496** *95*	**.90 950** *45*	**.91 408** *95*
.87 867 *94*	**.88 297** *44*	**.88 730** *94*	**.89 168** *44*	**.89 610** *94*	**.90 055** *44*	**.90 505** *94*	**.90 959** *44*	**.91 417** *94*
.87 875 *93*	**.88 305** *43*	**.88 739** *93*	**.89 177** *43*	**.89 619** *93*	**.90 064** *43*	**.90 514** *93*	**.90 968** *43*	**.91 426** *93*
.87 884 *92*	**.88 314** *42*	**.88 748** *92*	**.89 186** *42*	**.89 627** *92*	**.90 073** *42*	**.90 523** *92*	**.90 977** *42*	**.91 436** *92*
.87 892 *91*	**.88 323** *41*	**.88 757** *91*	**.89 194** *41*	**.89 636** *91*	**.90 082** *41*	**.90 532** *91*	**.90 986** *41*	**.91 445** *91*
.87 901 *90*	**.88 331** *40*	**.88 765** *90*	**.89 203** *40*	**.89 645** *90*	**.90 091** *40*	**.90 541** *90*	**.90 995** *40*	**.91 454** *90*
.87 909 *89*	**.88 340** *39*	**.88 774** *89*	**.89 212** *39*	**.89 654** *89*	**.90 100** *39*	**.90 550** *89*	**.91 005** *39*	**.91 463** *89*
.87 918 *88*	**.88 348** *38*	**.88 783** *88*	**.89 221** *38*	**.89 663** *88*	**.90 109** *38*	**.90 559** *88*	**.91 014** *38*	**.91 472** *88*
.87 927 *87*	**.88 357** *37*	**.88 791** *87*	**.89 230** *37*	**.89 672** *87*	**.90 118** *37*	**.90 568** *87*	**.91 023** *37*	**.91 482** *87*
.87 935 *86*	**.88 366** *36*	**.88 800** *86*	**.89 238** *36*	**.89 681** *86*	**.90 127** *36*	**.90 577** *86*	**.91 032** *36*	**.91 491** *86*
.87 944 *85*	**.88 374** *35*	**.88 809** *85*	**.89 247** *35*	**.89 690** *85*	**.90 136** *35*	**.90 586** *85*	**.91 041** *35*	**.91 500** *85*
.87 952 *84*	**.88 383** *34*	**.88 818** *84*	**.89 256** *34*	**.89 699** *84*	**.90 145** *34*	**.90 596** *84*	**.91 050** *34*	**.91 509** *84*
.87 961 *83*	**.88 392** *33*	**.88 826** *83*	**.89 265** *33*	**.89 707** *83*	**.90 154** *33*	**.90 605** *83*	**.91 059** *33*	**.91 519** *83*
.87 969 *82*	**.88 400** *32*	**.88 835** *82*	**.89 274** *32*	**.89 716** *82*	**.90 163** *32*	**.90 614** *82*	**.91 069** *32*	**.91 528** *82*
.87 978 *81*	**.88 409** *31*	**.88 844** *81*	**.89 283** *31*	**.89 725** *81*	**.90 172** *31*	**.90 623** *81*	**.91 078** *31*	**.91 537** *81*
.87 987 *80*	**.88 418** *30*	**.88 853** *80*	**.89 291** *30*	**.89 734** *80*	**.90 181** *30*	**.90 632** *80*	**.91 087** *30*	**.91 546** *80*
.87 995 *79*	**.88 426** *29*	**.88 861** *79*	**.89 300** *29*	**.89 743** *79*	**.90 190** *29*	**.90 641** *79*	**.91 096** *29*	**.91 555** *79*
.88 004 *78*	**.88 435** *28*	**.88 870** *78*	**.89 309** *28*	**.89 752** *78*	**.90 199** *28*	**.90 650** *78*	**.91 105** *28*	**.91 565** *78*
.88 012 *77*	**.88 444** *27*	**.88 879** *77*	**.89 318** *27*	**.89 761** *77*	**.90 208** *27*	**.90 659** *77*	**.91 114** *27*	**.91 574** *77*
.88 021 *76*	**.88 452** *26*	**.88 888** *76*	**.89 327** *26*	**.89 770** *76*	**.90 217** *26*	**.90 668** *76*	**.91 123** *26*	**.91 583** *76*
0.88 030 *75*	**0.88 461** *25*	**0.88 896** *75*	**0.89 335** *25*	**0.89 779** *75*	**0.90 226** *25*	**0.90 677** *75*	**0.91 133** *25*	**0.91 592** *75*
.88 038 *74*	**.88 470** *24*	**.88 905** *74*	**.89 344** *24*	**.89 787** *74*	**.90 235** *24*	**.90 686** *74*	**.91 142** *24*	**.91 602** *74*
.88 047 *73*	**.88 478** *23*	**.88 914** *73*	**.89 353** *23*	**.89 796** *73*	**.90 244** *23*	**.90 695** *73*	**.91 151** *23*	**.91 611** *73*
.88 055 *72*	**.88 487** *22*	**.88 923** *72*	**.89 362** *22*	**.89 805** *72*	**.90 253** *22*	**.90 704** *72*	**.91 160** *22*	**.91 620** *72*
.88 064 *71*	**.88 496** *21*	**.88 931** *71*	**.89 371** *21*	**.89 814** *71*	**.90 262** *21*	**.90 713** *71*	**.91 169** *21*	**.91 629** *71*
.88 073 *70*	**.88 504** *20*	**.88 940** *70*	**.89 380** *20*	**.89 823** *70*	**.90 271** *20*	**.90 722** *70*	**.91 178** *20*	**.91 639** *70*
.88 081 *69*	**.88 513** *19*	**.88 949** *69*	**.89 388** *19*	**.89 832** *69*	**.90 280** *19*	**.90 732** *69*	**.91 188** *19*	**.91 648** *69*
.88 090 *68*	**.88 522** *18*	**.88 958** *68*	**.89 397** *18*	**.89 841** *68*	**.90 289** *18*	**.90 741** *68*	**.91 197** *18*	**.91 657** *68*
.88 098 *67*	**.88 530** *17*	**.88 966** *67*	**.89 406** *17*	**.89 850** *67*	**.90 298** *17*	**.90 750** *67*	**.91 206** *17*	**.91 666** *67*
.88 107 *66*	**.88 539** *16*	**.88 975** *66*	**.89 415** *16*	**.89 859** *66*	**.90 307** *16*	**.90 759** *66*	**.91 215** *16*	**.91 676** *66*
.88 116 *65*	**.88 548** *15*	**.88 984** *65*	**.89 424** *15*	**.89 868** *65*	**.90 316** *15*	**.90 768** *65*	**.91 224** *15*	**.91 685** *65*
.88 124 *64*	**.88 556** *14*	**.88 993** *64*	**.89 433** *14*	**.89 877** *64*	**.90 325** *14*	**.90 777** *64*	**.91 233** *14*	**.91 694** *64*
.88 133 *63*	**.88 565** *13*	**.89 001** *63*	**.89 441** *13*	**.89 886** *63*	**.90 334** *13*	**.90 786** *63*	**.91 243** *13*	**.91 703** *63*
.88 141 *62*	**.88 574** *12*	**.89 010** *62*	**.89 450** *12*	**.89 894** *62*	**.90 343** *12*	**.90 795** *62*	**.91 252** *12*	**.91 713** *62*
.88 150 *61*	**.88 582** *11*	**.89 019** *61*	**.89 459** *11*	**.89 903** *61*	**.90 352** *11*	**.90 804** *61*	**.91 261** *11*	**.91 722** *61*
.88 159 *60*	**.88 591** *10*	**.89 028** *60*	**.89 468** *10*	**.89 912** *60*	**.90 361** *10*	**.90 813** *60*	**.91 270** *10*	**.91 731** *60*
.88 167 *59*	**.88 600** *09*	**.89 036** *59*	**.89 477** *09*	**.89 921** *59*	**.90 370** *09*	**.90 822** *59*	**.91 279** *09*	**.91 740** *59*
.88 176 *58*	**.88 609** *08*	**.89 045** *58*	**.89 486** *08*	**.89 930** *58*	**.90 379** *08*	**.90 831** *58*	**.91 288** *08*	**.91 750** *58*
.88 184 *57*	**.88 617** *07*	**.89 054** *57*	**.89 495** *07*	**.89 939** *57*	**.90 388** *07*	**.90 841** *57*	**.91 298** *07*	**.91 759** *57*
.88 193 *56*	**.88 626** *06*	**.89 063** *56*	**.89 503** *06*	**.89 948** *56*	**.90 397** *06*	**.90 850** *56*	**.91 307** *06*	**.91 768** *56*
.88 202 *55*	**.88 635** *05*	**.89 071** *55*	**.89 512** *05*	**.89 957** *55*	**.90 406** *05*	**.90 859** *55*	**.91 316** *05*	**.91 778** *55*
.88 210 *54*	**.88 643** *04*	**.89 080** *54*	**.89 521** *04*	**.89 966** *54*	**.90 415** *04*	**.90 868** *54*	**.91 325** *04*	**.91 787** *54*
.88 219 *53*	**.88 652** *03*	**.89 089** *53*	**.89 530** *03*	**.89 975** *53*	**.90 424** *03*	**.90 877** *53*	**.91 334** *03*	**.91 796** *53*
.88 228 *52*	**.88 661** *02*	**.89 098** *52*	**.89 539** *02*	**.89 984** *52*	**.90 433** *02*	**.90 886** *52*	**.91 344** *02*	**.91 805** *52*
.88 236 *51*	**.88 669** *01*	**.89 107** *51*	**.89 548** *01*	**.89 993** *51*	**.90 442** *01*	**.90 895** *51*	**.91 353** *01*	**.91 815** *51*
0.88 245 *50*	**0.88 678** *00*	**0.89 115** *50*	**0.89 556** *00*	**0.90 002** *50*	**0.90 451** *00*	**0.90 904** *50*	**0.91 362** *00*	**0.91 824** *50*

Find your entering number in the column of heavy print. If there isn't a perfect match, go to the next larger number. The last part of the gaussian is beside it; the first part is above the column.

Table 7

0°

	.'0	.'1	.'2	.'3	.'4	.'5	.'6	.'7	.'8	.'9
0'		3.3802	3.0792	2.9031	2.7782	2.6812	2.6021	2.5351	2.4771	2.4260
1'	2.3802	2.3388	2.3010	2.2663	2.2341	2.2041	2.1761	2.1498	2.1249	2.1015
2'	2.0792	2.0580	2.0378	2.0185	2.0000	1.9823	1.9652	1.9488	1.9331	1.9178
3'	1.9031	1.8888	1.8751	1.8617	1.8487	1.8361	1.8239	1.8120	1.8004	1.7891
4'	1.7782	1.7674	1.7570	1.7467	1.7368	1.7270	1.7175	1.7081	1.6990	1.6900
5'	1.6812	1.6726	1.6642	1.6559	1.6478	1.6398	1.6320	1.6243	1.6168	1.6094
6'	1.6021	1.5949	1.5878	1.5809	1.5740	1.5673	1.5607	1.5541	1.5477	1.5414
7'	1.5351	1.5290	1.5229	1.5169	1.5110	1.5051	1.4994	1.4937	1.4881	1.4826
8'	1.4771	1.4717	1.4664	1.4611	1.4559	1.4508	1.4457	1.4407	1.4357	1.4308
9'	1.4260	1.4212	1.4164	1.4117	1.4071	1.4025	1.3979	1.3934	1.3890	1.3846
10'	1.3802	1.3759	1.3716	1.3674	1.3632	1.3590	1.3549	1.3508	1.3468	1.3428
11'	1.3388	1.3349	1.3310	1.3271	1.3233	1.3195	1.3158	1.3120	1.3083	1.3047
12'	1.3010	1.2974	1.2939	1.2903	1.2868	1.2833	1.2798	1.2764	1.2730	1.2696
13'	1.2663	1.2629	1.2596	1.2564	1.2531	1.2499	1.2467	1.2435	1.2403	1.2372
14'	1.2341	1.2310	1.2279	1.2249	1.2218	1.2188	1.2159	1.2129	1.2099	1.2070
15'	1.2041	1.2012	1.1984	1.1955	1.1927	1.1899	1.1871	1.1843	1.1816	1.1788
16'	1.1761	1.1734	1.1707	1.1680	1.1654	1.1627	1.1601	1.1575	1.1549	1.1523
17'	1.1498	1.1472	1.1447	1.1422	1.1397	1.1372	1.1347	1.1322	1.1298	1.1274
18'	1.1249	1.1225	1.1201	1.1178	1.1154	1.1130	1.1107	1.1084	1.1061	1.1037
19'	1.1015	1.0992	1.0969	1.0947	1.0924	1.0902	1.0880	1.0857	1.0835	1.0814
20'	1.0792	1.0770	1.0749	1.0727	1.0706	1.0685	1.0663	1.0642	1.0621	1.0601
21'	1.0580	1.0559	1.0539	1.0518	1.0498	1.0478	1.0458	1.0438	1.0418	1.0398
22'	1.0378	1.0358	1.0339	1.0319	1.0300	1.0280	1.0261	1.0242	1.0223	1.0204
23'	1.0185	1.0166	1.0147	1.0129	1.0110	1.0091	1.0073	1.0055	1.0036	1.0018
24'	1.0000	0.9982	0.9964	0.9946	0.9928	0.9910	0.9893	0.9875	0.9858	0.9840
25'	0.9823	0.9805	0.9788	0.9771	0.9754	0.9737	0.9720	0.9703	0.9686	0.9669
26'	0.9652	0.9636	0.9619	0.9603	0.9586	0.9570	0.9553	0.9537	0.9521	0.9505
27'	0.9488	0.9472	0.9456	0.9440	0.9425	0.9409	0.9393	0.9377	0.9362	0.9346
28'	0.9331	0.9315	0.9300	0.9284	0.9269	0.9254	0.9238	0.9223	0.9208	0.9193
29'	0.9178	0.9163	0.9148	0.9133	0.9119	0.9104	0.9089	0.9075	0.9060	0.9045
30'	0.9031	0.9016	0.9002	0.8988	0.8973	0.8959	0.8945	0.8931	0.8917	0.8903
31'	0.8888	0.8875	0.8861	0.8847	0.8833	0.8819	0.8805	0.8792	0.8778	0.8764
32'	0.8751	0.8737	0.8724	0.8710	0.8697	0.8683	0.8670	0.8657	0.8643	0.8630
33'	0.8617	0.8604	0.8591	0.8578	0.8565	0.8552	0.8539	0.8526	0.8513	0.8500
34'	0.8487	0.8475	0.8462	0.8449	0.8437	0.8424	0.8411	0.8399	0.8386	0.8374
35'	0.8361	0.8349	0.8337	0.8324	0.8312	0.8300	0.8288	0.8275	0.8263	0.8251
36'	0.8239	0.8227	0.8215	0.8203	0.8191	0.8179	0.8167	0.8155	0.8144	0.8132
37'	0.8120	0.8108	0.8097	0.8085	0.8073	0.8062	0.8050	0.8039	0.8027	0.8016
38'	0.8004	0.7993	0.7981	0.7970	0.7959	0.7948	0.7936	0.7925	0.7914	0.7903
39'	0.7891	0.7880	0.7869	0.7858	0.7847	0.7836	0.7825	0.7814	0.7803	0.7792
40'	0.7782	0.7771	0.7760	0.7749	0.7738	0.7728	0.7717	0.7706	0.7696	0.7685
41'	0.7674	0.7664	0.7653	0.7643	0.7632	0.7622	0.7611	0.7601	0.7590	0.7580
42'	0.7570	0.7559	0.7549	0.7539	0.7528	0.7518	0.7508	0.7498	0.7488	0.7478
43'	0.7467	0.7457	0.7447	0.7437	0.7427	0.7417	0.7407	0.7397	0.7387	0.7377
44'	0.7368	0.7358	0.7348	0.7338	0.7328	0.7319	0.7309	0.7299	0.7289	0.7280
45'	0.7270	0.7260	0.7251	0.7241	0.7232	0.7222	0.7212	0.7203	0.7193	0.7184
46'	0.7175	0.7165	0.7156	0.7146	0.7137	0.7128	0.7118	0.7109	0.7100	0.7090
47'	0.7081	0.7072	0.7063	0.7054	0.7044	0.7035	0.7026	0.7017	0.7008	0.6999
48'	0.6990	0.6981	0.6972	0.6963	0.6954	0.6945	0.6936	0.6927	0.6918	0.6909
49'	0.6900	0.6891	0.6882	0.6874	0.6865	0.6856	0.6847	0.6839	0.6830	0.6821
50'	0.6812	0.6804	0.6795	0.6786	0.6778	0.6769	0.6761	0.6752	0.6743	0.6735
51'	0.6726	0.6718	0.6709	0.6701	0.6692	0.6684	0.6676	0.6667	0.6659	0.6650
52'	0.6642	0.6634	0.6625	0.6617	0.6609	0.6601	0.6592	0.6584	0.6576	0.6568
53'	0.6559	0.6551	0.6543	0.6535	0.6527	0.6519	0.6510	0.6502	0.6494	0.6486
54'	0.6478	0.6470	0.6462	0.6454	0.6446	0.6438	0.6430	0.6422	0.6414	0.6406
55'	0.6398	0.6391	0.6383	0.6375	0.6367	0.6359	0.6351	0.6344	0.6336	0.6328
56'	0.6320	0.6312	0.6305	0.6297	0.6289	0.6282	0.6274	0.6266	0.6259	0.6251
57'	0.6243	0.6236	0.6228	0.6221	0.6213	0.6205	0.6198	0.6190	0.6183	0.6175
58'	0.6168	0.6160	0.6153	0.6145	0.6138	0.6131	0.6123	0.6116	0.6108	0.6101
59'	0.6094	0.6086	0.6079	0.6072	0.6064	0.6057	0.6050	0.6042	0.6035	0.6028

0°

Using Predicted Lunar Distances

The tables and procedures presented in this book are self contained, and do not require other data beyond what is included in present day almanacs of the bodies being used (GHA, Dec, HP). The lunar sight reduction process, however, can be notably quicker when pre-computed lunar distance data are available.

In the early days of celestial navigation when lunars were part of the routine, the Nautical Almanac and other publications included computed lunar distances that could be used to both predict the best sights to take and to evaluate the actual sights once taken. The most common format for these predictions gave the distances every 3 hours for the selected bodies that would yield the best lunar sights.

These data have not been available from official government sources since about 1905, but several individuals have provided these predictions each year for several years now, and thus the data are once again readily available to mariners. Notable examples of this work include that of Steven Wepster of the University of Utrech and Frank Reed, coordinator of the NavList discussion group (www.fer3.com/arc), which specializes in lunar theory and practice among many other topics. Examples from each source are shown below.

JULY 2010

	° ′	P.L.	° ′	P.L.	° ′	P.L.	° ′	P.L.	° ′	P.L.
4 UT	+Kaus Aust.		+Nunki		+Jupiter		−Hamal		−Sun	
0	90 55.2	3071	82 58.1	3007	6 57.6	6619	32 42.0	3063	96 45.8	3356
3	92 23.9	3063	84 28.1	2999	7 36.8	5374	31 13.1	3061	95 22.7	3347
6	93 52.8	3054	85 58.4	2990	8 29.0	4644	29 44.2	3059	93 59.4	3337
9	95 21.9	3045	87 28.8	2980	9 30.7	4186	28 15.2	3057	92 35.9	3327
12	96 51.2	3036	88 59.4	2971	10 39.4	3883	26 46.2	3058	91 12.3	3317
15	98 20.7	3026	90 30.2	2960	11 53.0	3671	25 17.2	3058	89 48.4	3306
18	99 50.3	3016	92 1.2	2950	13 10.3	3519	23 48.2	3061	88 24.3	3294
21	101 20.2	3006	93 32.5	2939	14 30.3	3405	22 19.2	3067	87 0.0	3282

Sample data from Steve Wepster, available at www.staff.science.uu.nl/~wepst101/tables.html (archived at www.starpath.com/navpubs). He offers distances to the best five bodies, at 3-hour intervals each day. The data are presented in print ready pdf documents.

Lunars Almanac for July 4, 2010, Date and Times are GMT.								
	0:00	3:00	6:00	9:00	12:00	15:00	18:00	21:00
Moon's HP	54.65	54.71	54.77	54.83	54.88	54.95	55.02	55.08
Sun SD:	15.74							
The Sun	96° 45.8'	95° 22.7'	93° 59.4'	92° 36.0'	91° 12.3'	89° 48.4'	88° 24.4'	87° 00.0'
Jupiter	---	---	---	---	10° 39.4'	11° 53.0'	13° 10.3'	14° 30.3'
Hamal	32° 42.1'	31° 13.2'	29° 44.2'	28° 15.2'	26° 46.2'	25° 17.2'	23° 48.2'	22° 19.3'
Kaus Aust.	90° 55.1'	92° 23.9'	93° 52.8'	95° 21.9'	96° 51.1'	98° 20.6'	99° 50.3'	101° 20.2'
Nunki	82° 58.0'	84° 28.1'	85° 58.3'	87° 28.8'	88° 59.4'	90° 30.2'	92° 01.2'	93° 32.5'

Sample data from Frank Reed, available at www.historicalatlas.com/lunars/lunars_pre_v5.html (archived at www.starpath.com/navpubs). He offers data for all reasonable bodies at 1- , 2-, or 3-hour intervals each day. The above is an excerpt to compare with the Wepster format. The data are presented as web-page tables, covering the bodies chosen by the user.

Prior to an ocean voyage or terrestrial expedition, the navigator can quickly print out these tables for the dates underway and use them as called for to expedite the lunar process.

The traditional way to interpolate predicted distances data for the actual distance observed makes use of Proportional Logarithms. For convenience to the navigator, a set of these tables, customized to this application, along with instructions on using them is included in this Appendix.

Proportional Logarithms

Degree:minute, or Hour:minute

SECONDS OF TIME OR ARC

	0:00	0:01	0:02	0:03	0:04	0:05	0:06	0:07	0:08	0:09	0:10	0:11	0:12	0:13	0:14	0:15	0:16	0:17	
0	#VALUE!	2.2553	1.9542	1.7782	1.6532	1.5563	1.4771	1.4102	1.3522	1.3010	1.2553	1.2139	1.1761	1.1413	1.1091	1.0792	1.0512	1.0248	
2	3.7324	2.2410	1.9471	1.7734	1.6496	1.5534	1.4747	1.4081	1.3504	1.2994	1.2538	1.2126	1.1749	1.1402	1.1081	1.0782	1.0502	1.0240	
4	3.4314	2.2272	1.9400	1.7686	1.6460	1.5506	1.4723	1.4061	1.3486	1.2978	1.2524	1.2113	1.1737	1.1391	1.1071	1.0773	1.0493	1.0231	
6	3.2553	2.2139	1.9331	1.7639	1.6425	1.5477	1.4699	1.4040	1.3468	1.2962	1.2510	1.2099	1.1725	1.1380	1.1061	1.0763	1.0484	1.0223	0.'1
8	3.1303	2.2009	1.9262	1.7593	1.6390	1.5449	1.4676	1.4020	1.3450	1.2946	1.2495	1.2086	1.1713	1.1369	1.1050	1.0753	1.0475	1.0214	
10	3.0334	2.1883	1.9195	1.7547	1.6355	1.5421	1.4652	1.4000	1.3432	1.2931	1.2481	1.2073	1.1701	1.1358	1.1040	1.0744	1.0467	1.0206	
12	2.9542	2.1761	1.9128	1.7501	1.6320	1.5393	1.4629	1.3979	1.3415	1.2915	1.2467	1.2061	1.1689	1.1347	1.1030	1.0734	1.0458	1.0197	0.'2
14	2.8873	2.1642	1.9063	1.7456	1.6286	1.5365	1.4606	1.3959	1.3397	1.2899	1.2453	1.2048	1.1677	1.1336	1.1020	1.0725	1.0449	1.0189	
16	2.8293	2.1526	1.8999	1.7412	1.6252	1.5337	1.4582	1.3939	1.3379	1.2883	1.2438	1.2035	1.1665	1.1325	1.1009	1.0715	1.0440	1.0181	
18	2.7782	2.1413	1.8935	1.7368	1.6218	1.5310	1.4559	1.3919	1.3362	1.2868	1.2424	1.2022	1.1654	1.1314	1.0999	1.0706	1.0431	1.0172	0.'3
20	2.7324	2.1303	1.8873	1.7324	1.6185	1.5283	1.4536	1.3900	1.3345	1.2852	1.2410	1.2009	1.1642	1.1303	1.0989	1.0696	1.0422	1.0164	
22	2.6910	2.1196	1.8811	1.7281	1.6151	1.5256	1.4514	1.3880	1.3327	1.2837	1.2396	1.1996	1.1630	1.1292	1.0979	1.0687	1.0413	1.0156	
24	2.6532	2.1091	1.8751	1.7238	1.6118	1.5229	1.4491	1.3860	1.3310	1.2821	1.2382	1.1984	1.1619	1.1282	1.0969	1.0678	1.0404	1.0147	0.'4
26	2.6185	2.0989	1.8691	1.7196	1.6085	1.5202	1.4468	1.3841	1.3293	1.2806	1.2368	1.1971	1.1607	1.1271	1.0959	1.0668	1.0395	1.0139	
28	2.5863	2.0889	1.8632	1.7154	1.6053	1.5175	1.4446	1.3821	1.3276	1.2791	1.2355	1.1958	1.1595	1.1260	1.0949	1.0659	1.0387	1.0131	
30	2.5563	2.0792	1.8573	1.7112	1.6021	1.5149	1.4424	1.3802	1.3259	1.2775	1.2341	1.1946	1.1584	1.1249	1.0939	1.0649	1.0378	1.0122	0.'5
32	2.5283	2.0696	1.8516	1.7071	1.5989	1.5123	1.4401	1.3783	1.3242	1.2760	1.2327	1.1933	1.1572	1.1239	1.0929	1.0640	1.0369	1.0114	
34	2.5019	2.0603	1.8459	1.7030	1.5957	1.5097	1.4379	1.3764	1.3225	1.2745	1.2313	1.1921	1.1561	1.1228	1.0919	1.0631	1.0360	1.0106	
36	2.4771	2.0512	1.8403	1.6990	1.5925	1.5071	1.4357	1.3745	1.3208	1.2730	1.2300	1.1908	1.1549	1.1217	1.0909	1.0621	1.0352	1.0098	0.'6
38	2.4536	2.0422	1.8348	1.6950	1.5894	1.5045	1.4335	1.3726	1.3191	1.2715	1.2286	1.1896	1.1538	1.1207	1.0899	1.0612	1.0343	1.0089	
40	2.4314	2.0334	1.8293	1.6910	1.5863	1.5019	1.4314	1.3707	1.3174	1.2700	1.2272	1.1883	1.1526	1.1196	1.0889	1.0603	1.0334	1.0081	
42	2.4102	2.0248	1.8239	1.6871	1.5832	1.4994	1.4292	1.3688	1.3158	1.2685	1.2259	1.1871	1.1515	1.1186	1.0880	1.0594	1.0326	1.0073	0.'7
44	2.3900	2.0164	1.8186	1.6832	1.5801	1.4969	1.4270	1.3669	1.3141	1.2670	1.2245	1.1859	1.1503	1.1175	1.0870	1.0585	1.0317	1.0065	
46	2.3707	2.0081	1.8133	1.6793	1.5771	1.4943	1.4249	1.3650	1.3124	1.2655	1.2232	1.1846	1.1492	1.1164	1.0860	1.0575	1.0308	1.0057	
48	2.3522	2.0000	1.8081	1.6755	1.5740	1.4918	1.4228	1.3632	1.3108	1.2640	1.2218	1.1834	1.1481	1.1154	1.0850	1.0566	1.0300	1.0049	0.'8
50	2.3345	1.9920	1.8030	1.6717	1:5710	1.4894	1.4206	1.3613	1.3091	1.2626	1.2205	1.1822	1.1469	1.1143	1.0840	1.0557	1.0291	1.0040	
52	2.3174	1.9842	1.7979	1.6679	1.5680	1.4869	1.4185	1.3595	1.3075	1.2611	1.2192	1.1809	1.1458	1.1133	1.0831	1.0548	1.0282	1.0032	
54	2.3010	1.9765	1.7929	1.6642	1.5651	1.4844	1.4164	1.3576	1.3059	1.2596	1.2178	1.1797	1.1447	1.1123	1.0821	1.0539	1.0274	1.0024	0.'9
56	2.2852	1.9690	1.7879	1.6605	1.5621	1.4820	1.4143	1.3558	1.3043	1.2582	1.2165	1.1785	1.1436	1.1112	1.0811	1.0530	1.0265	1.0016	
58	2.2700	1.9615	1.7830	1.6568	1.5592	1.4795	1.4122	1.3540	1.3026	1.2567	1.2152	1.1773	1.1424	1.1102	1.0801	1.0521	1.0257	1.0008	
	0° 0'	0°1'	0° 2'	0° 3'	0° 4'	0° 5'	0° 6'	0° 7'	0° 8'	0° 9'	0° 10'	0° 11'	0° 12'	0° 13'	0° 14'	0° 15'	0° 16'	0° 17'	

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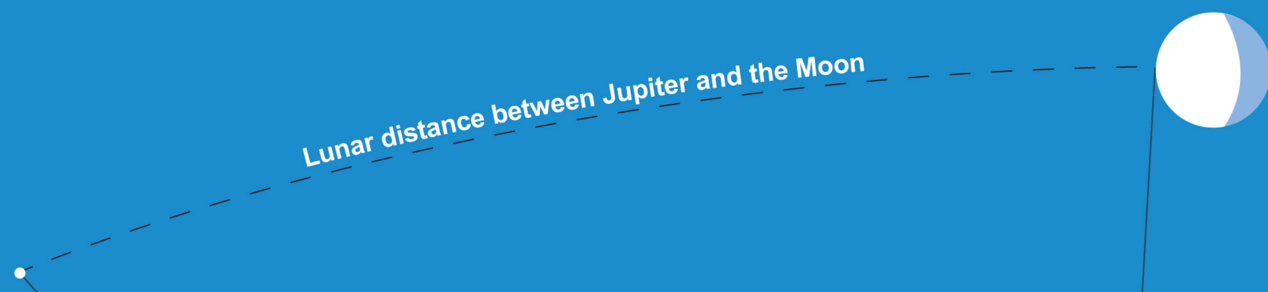


Celestial navigation is a way to find your latitude and longitude on earth using a sextant to measure the angular heights of celestial bodies above the horizon. It has been used by mariners at sea and explorers on land for three hundred years, and it is still used today as a dependable backup to modern electronic navigation.

Routine celestial navigation relies upon accurate time (Universal Time) to find the longitude of a position (latitude does not require time). Advanced celestial navigators can find longitude *without knowing the time* using a technique called Lunar Distance. In this technique, the sextant is used to measure the angular (diagonal) distance between the moon and another celestial body. Since this distance slowly changes as the moon moves eastward though the stars, it can be used to find Universal Time, which is needed to complete the longitude determination.

The process of finding longitude from lunar distance, however, requires special tables that have not been published in the *Nautical Almanac* or other sources since the early 1900s. Although software solutions are now available, most advanced celestial navigators are very grateful to navigation historian Bruce Stark for creating these printed tables dedicated to this task. They have been used and tested by mariners for more than 15 years and are praised by experts for their ingenuity and ease of use in solving this complex navigation exercise—which all agree is the hallmark of an expert celestial navigator.

With *The Stark Tables* in your nav station, you no longer have to fear losing power to your electronic navigation aids, nor are you dependent on accurate time from any official broadcast.

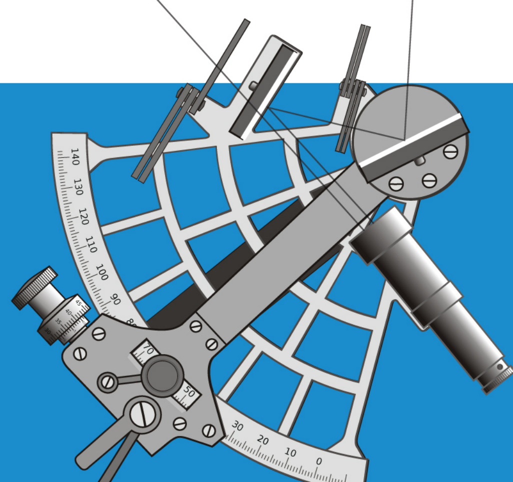
Besides their practical use in back up navigation, historians have used these tables for years to interpret the logbooks of Lewis and Clark, David Thompson, James Cook, Matthew Flinders, George Vancouver, Nathaniel Bowditch, and other notable explorers and sea captains.

"Captain Cook would have relished using these tables, had they been available to him then."

— George Huxtable, FRIN

"It is remarkable in this day when the very survival of celestial navigation seems in question, that an individual should suddenly appear on the scene and present to the world such a brilliant piece of work. Stark has rendered a great service to the celestial navigation community."

— Robert Eno, *The Navigator's Newsletter*



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