

Sight reduction tables

I have written a computer program to calculate and print out sight reduction tables similar to the classic 'Air Tables'.

When running the program one can select the Latitude and Declination range to be printed which means that in practice there is no need to make a thick book; I recommend printing only the few pages covering the range of Latitude and Declination, plus some safety margin, relevant to the planned voyage.

Tables

The tables display calculated Altitude and Azimuth for LHA versus Declination, one page for each degree of Latitude. A snippet of a page is reproduced here:

LATITUDE = 42.00

DEC =	19.00	19.30	20.00	20.30	21.00	21.30	22.00	22.30	23.00	23.30
LHA										
0	67.00 180	67.30 180	68.00 180	68.30 180	69.00 180	69.30 180	70.00 180	70.30 180	71.00 180	71.30 180
1	66.59 182	67.29 182	67.59 182	68.29 183	68.59 183	69.29 183	69.59 183	70.29 183	70.59 183	71.29 183
2	66.56 185	67.26 185	67.56 185	68.26 185	68.56 185	69.26 185	69.56 185	70.26 186	70.56 186	71.26 186
3	66.52 187	67.21 187	67.51 187	68.21 188	68.51 188	69.21 188	69.51 188	70.20 188	70.50 188	71.20 189
4	66.45 190	67.15 190	67.44 190	68.14 190	68.44 190	69.14 191	69.43 191	70.13 191	70.43 191	71.12 191
5	66.37 192	67.06 192	67.36 192	68.05 193	68.35 193	69.04 193	69.34 193	70.03 194	70.33 194	71.02 194
6	66.27 194	66.56 195	67.25 195	67.55 195	68.24 195	68.53 196	69.23 196	69.52 196	70.21 197	70.50 197
7	66.15 197	66.44 197	67.							

The Declination is printed across the top, in half-degree (30 minute) intervals, and the LHA down the vertical axis, starting at zero and going up to 109 degrees (by which time the sun is below the horizon in normal latitudes). Each entry contains a two number pair: the Calculated Altitude and the Calculated Azimuth. Look at the values in the table above for LHA = 3° and Declination = 20° 30'; the Calculated Altitude is 68° 21' and the Calculated Azimuth is 188°.

The format of the tables is always dd.mm, that is to say degrees, a decimal point, then minutes.

Sign convention

I have used the following convention – it may be idiosyncratic:

Latitude is positive if north, negative if south
Declination is positive if north and negative if south
LHA is positive when the sun is west of one's estimated position
Azimuth is in degrees true.

Only positive LHA is shown, so if LHA is negative, i.e. the sun is to the east:

Altitude can be used directly
Azimuth = 360 – tabulated Azimuth.

Files for Download

This site only contains a small example file of a pre-prepared table, so you have to compute and print your own. The files available for down-load are:

1. main.c

This is the so called 'source code' of the program which I use to generate the tables. You should not really need this file, but it is included for interest's sake or for those who do not use either a PC running Microsoft Windows or an Apple Mac running OS X, and therefore need to compile the program.

Don't worry if this means nothing to you – you don't need the file in that case! It is customary at this point to welcome feedback on the program; I am already aware that my code contains many infelicities, but if you spot that the program actually gives incorrect answers please do let me know.

2. tmp.rtf

This is an example of the output of the program. It is a text file which is readable by Microsoft 'Word' or virtually any other word processing package. The format is known as 'Rich Text Format' which determines the font, its size and spacing, so one degree of Latitude should fit exactly on one page.

3. Two directories (aka folders), called 'PC' and 'Apple MAC'

These each contain a single file, 'gen_table' which is the actual program that creates the tables (as rtf documents, see above). There are two folders but the contents of only one need be downloaded according to the type of computer you are using.

Generating tables

Having downloaded the program file 'gen_table', (it may be shown as 'gen_table.exe' on some computers), you are ready to run it. To do so open a command window:

PCs: Click on the Windows icon in the south-west corner of the screen, then click on 'Run...' and type 'cmd' in the dialogue box displayed.

MACs: In 'Finder' look in 'Applications' then 'Utilities' and then click on 'Terminal'.

In both cases you must change directory (command is 'cd') to wherever you have put the downloaded file 'gen_table'. At this point you may run the program by typing:

PCs:

```
gen_table 0 2 15 20
```

MACs:

```
./gen_table 0 2 15 20
```

What this does is run the program, and you should see pages of text rushing past on the screen. The four numbers are the variables or 'arguments':

Start Latitude (=0 in the example above),
Finish Latitude (=2 in the example above),
Start Declination (=15 in the example above), and
Finish Declination (=20 in the example above).

Only 13 columns fit across an A4 sheet of paper, so I suggest that you always choose a Start Declination and a Finish Declination that are 6 degrees apart (the Declination is printed every half degree, so 6 degrees gives 13 columns).

Important: A peculiarity of the program is that the input values are in degrees, not degrees.minutes, so to start at a Declination of 17° 30' one types 17.5. The output of the program is always in degrees.minutes however.

To print to a file, which is in general what one wants to do, type

```
gen_table 45 55 17.5 23.5 > tmp.rtf
```

This directs the output to a file called tmp.rtf . There's nothing magic about this name, by all means change it to any name you like, such as "Some_output_from_this_rotten_programme.rtf". But keep the .rtf on the end.

Printing tables

Open the rtf file just created in Microsoft Word or your favourite word processor and it should look neat; Latitude value printed at the top, 13 columns of Declination spaced half a degree apart and a row for every degree of LHA from 0 to 109, all fitting on a single A4 page for every degree of latitude printed.

Assuming it does look like this, just print the file just as you would any normal Word document. The paper size has to be A4. You may have to fiddle with the settings of the paper margins on your printer so that it prints all the way to the edge of the paper.

Using the tables and plotting a position line

It is assumed that you are already familiar with using a sextant and the concepts by which one uses sun sights to establish a position line – terms such as Declination and LHA have already been used. However here is the way I think about the problem and the way I use the tables:

1. Measure the True Altitude

Using the sextant measure the altitude, applying all the normal corrections for parallax, refraction, height of eye and semi-diameter. This is the True Altitude, TA. Record to the nearest second the exact time at which the altitude was measured.

2. Look up Declination and GHA

At any given moment the sun is due overhead at one spot, and with a nautical almanac one can look up the Latitude (which is called Declination) and Longitude (which is called 'Greenwich Hour Angle') of this spot. These are usually tabulated every 2 hours and one has to interpolate for the exact time when the altitude was measured. One can use the tabulated Declination directly since it changes slowly, but must interpolate the GHA using the fact that the earth rotates 360° in 24 hours, thus 15° per hour. Use either a calculator or the GHA correction table in Reeds to work it out to the nearest second.

3. Choose a position to plot (CP)

For the purposes of a sun sight choose a position close to where you think you are but at a whole degree of Latitude, and at a Longitude such that the LHA (= GHA – Longitude) is a whole number of degrees.

4. Look up the Altitude and Azimuth

Use the tables! Now it's obvious why the CP has been chosen in the arcane way described above; since Longitude and LHA are whole numbers of degrees one has to interpolate only for Declination, which I find I can do in my head. The altitude taken from the table is known as Calculated Altitude, CA. If the LHA is positive, one can use the tabulated Azimuth directly, but if LHA is negative Azimuth = $360 - \text{tabulated Azimuth}$.

5. Difference the TA and the CA

This difference, in minutes, is the distance in nautical miles between the CP and the position line on which you actually are according to the sun sight; when TA is greater than CA your position must be closer to the sun than the CP – pretty obvious really, the closer one is to the sun the higher it is in the sky.

6. Plot the position line

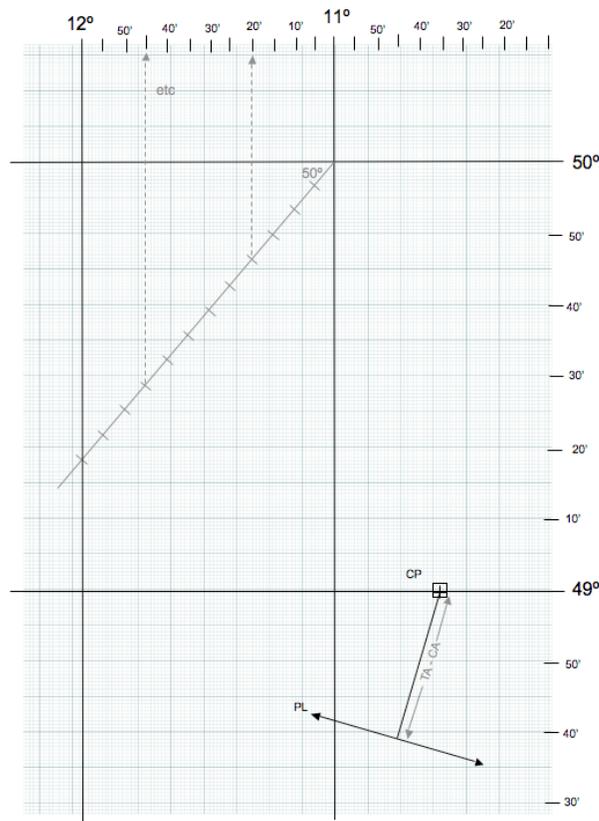
On a chart or plotting sheet draw a line through the CP at an angle equal to the Azimuth. Put a point on this line at the distance just calculated in step 5, towards or away from the sun as appropriate. Then draw a line through this point at right angles (to the Azimuth). This line is the position line, PL. You are on it somewhere, but not necessarily at the point closest to the CP.

Constructing a plotting sheet

The PL just obtained should be accurate to 1 or 2 nautical miles, so it's silly to throw away this accuracy by plotting on too small scale a chart. To preserve accuracy one needs a scale of a millimetre or two per mile, ie about 1:500,000.

Most ocean charts are 1:3,000,000 or 1:10,000,000, and besides, the chart would get covered in lines very rapidly if the chart itself was used to plot all position lines. So it is customary to create a plotting sheet showing latitude and longitude scales, and nothing else, and plot on this. I use graph paper ruled in mm and cm, as follows:

1. Draw parallel lines of Latitude, with degrees at 12 cm intervals. I mark in the margin each 10' of latitude (ie at 2cm intervals) so one minute is 2mm. On an A4 sheet one can fit a little more than 2°.
2. Construct the Longitude scale. Somewhere near the middle of the chart I draw a vertical line on a whole cm grid line (11° in the example below). Then draw a line, going through a point at the crossing of this Longitude line with a whole degree of Latitude, at an angle to the horizontal equal to the Latitude.
3. Along this line mark off each cm, up 12cm. Make a small mark on the top margin at the point directly above each of the 1cm spaced marks on the angled line. These little marks on the top margin are at 5' intervals of Longitude. Draw a heavy line at the 60' mark to signify a whole degree. The example below should make this a little clearer.



Although not strictly Mercator's projection, unless in polar latitudes the error may be ignored (the maximum possible error does not exceed 1 mile for latitudes less than 63° and is only 1.5 miles at 70°).

Transferring a position line to make a fix

Mark on the plotting sheet the CP and then plot the PL. As noted before you are somewhere along this line, but this isn't a fix, only a line; to get a fix one needs at least one other line which crosses the first at a reasonable angle. This can be from a simultaneous sight taken of a second heavenly body, such as the moon, but more frequently it is also from the sun, but taken at a different time so that the position lines cross. It's really only a 'running fix' as used in conventional coastal navigation.

I find it useful to take three sights in a day: one in mid morning when the Azimuth is about ESE, one near midday when it's nearly due south and another later in the afternoon when it's about WSW. These then all cross at angles near 60° which is perfect. Naturally one has to allow for movement of the boat between the sights by moving the earlier sight(s) by the course and distance travelled by Dead Reckoning. The sight thus moved is called a Transferred Position Line, TPL.