# Amplitude Problems

- Amplitude problems involve calculating the bearing at which an object *should* rise or set, and then comparing the calculation to actual observation in order to determine compass error. Amplitude is the easiest means of determining gyro error at sea, and can involve the sun, moon, or planets and stars.

- **Declination** - the angular distance north or south of the celestial equator, or the latitude of the point on earth directly beneath a celestial object. For example, if the sun's declination is 10° N, the sun is directly overhead at 10° N.

- **Amplitude** – the angular distance north or south of the equator of a celestial body on the horizon. Amplitudes are named based on the direction of the object and the difference from the equator. For example, if the sunset is observed at 280° T, the amplitude of the sun is W 10° N. If the sunrise is observed at 080° T, the amplitude of the sun is E 10° N. Amplitudes are found in Table 22 or Table 27 of Bowditch (depending on version used).

- **Horizon** – There are several different versions of "horizon" in celestial navigation. The simplest calculations are made when objects are on the "celestial" horizon as follows:
    - Sun – ideally when the sun's lower limb is 2/3 of a sun diameter (20 arc minutes) above the visual horizon.
    - Stars and Planets – ideally when the object is one sun diameter (30 arc minutes) above the visual horizon.
    - Moon – ideally when the upper limb of the moon is on the visual horizon.

- When objects are not on the "celestial" horizon, corrections must be made using Table 23 or Table 28 in Bowditch (depending on the version used). This correction has different rules depending on the body, season, and location.

Amplitude Problems

Amplitude Problems of the Sun on the Celestial Horizon

AMP D1. It is 20 May. You have taken an observation of the rising sun when its lower limb is approximately 2/3 of a sun's diameter above the horizon (in other words the sun's center is on the celestial horizon). The time of observation is 1000 UTC. Your latitude is 36° N.

a) What is the amplitude of the sun?
b) What true bearing should the sunrise be observed?
c) If you actually observe the sun rising at 068° T, what is the gyro error?

Answers:
a) E 25° N
b) 065° T
c) 3° W

| G.M.T. | | SUN G.H.A. | SUN Dec. |
|---|---|---|---|
| 20 | 00 | 180 53.7 | N19 54.8 |
| | 01 | 195 53.7 | 55.3 |
| | 02 | 210 53.6 | 55.8 |
| | 03 | 225 53.6 | · · 56.3 |
| | 04 | 240 53.6 | 56.9 |
| | 05 | 255 53.5 | 57.4 |
| | 06 | 270 53.5 | N19 57.9 |
| W | 07 | 285 53.5 | 58.4 |
| E | 08 | 300 53.4 | 59.0 |
| D | 09 | 315 53.4 | 19 59.5 |
| N | 10 | 330 53.4 | 20 00.0 |
| E | 11 | 345 53.3 | 00.5 |

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac.
The declination at 1000 UTC is N 20° 00'.

Step 2: Determine the ship's latitude at the time of observation.
Latitude – 36° N (given)

Step 3: Enter Table 22/27 in Bowditch with declination and latitude to determine the amplitude.
Declination: 20°
Latitude: 36°

Amplitudes

| Latitude | Declination 18°0 | 18°5 | 19°0 | 19°5 | 20°0 | 20°5 | 21°0 | 21°5 | 22°0 | 22°5 | 23°0 | 23°5 | 24°0 | Latitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0 | 18.0 | 18.5 | 19.0 | 19.5 | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | 0 |
| 10 | 18.3 | 18.8 | 19.3 | 19.8 | 20.3 | 20.8 | 21.3 | 21.8 | 22.4 | 22.9 | 23.4 | 23.9 | 24.4 | 10 |
| 15 | 18.7 | 19.2 | 19.7 | 20.2 | 20.7 | 21.3 | 21.8 | 22.3 | 22.8 | 23.3 | 23.9 | 24.4 | 24.9 | 15 |
| 20 | 19.2 | 19.7 | 20.3 | 20.8 | 21.3 | 21.9 | 22.4 | 23.0 | 23.5 | 24.0 | 24.6 | 25.1 | 25.6 | 20 |
| 25 | 19.9 | 20.5 | 21.1 | 21.6 | 22.2 | 22.7 | 23.3 | 23.9 | 24.4 | 25.0 | 25.5 | 26.1 | 26.7 | 25 |
| 30 | 20.9 | 21.5 | 22.1 | 22.7 | 23.3 | 23.9 | 24.4 | 25.0 | 25.6 | 26.2 | 26.8 | 27.4 | 28.0 | 30 |
| 32 | 21.4 | 22.0 | 22.6 | 23.2 | 23.8 | 24.4 | 25.0 | 25.6 | 26.2 | 26.8 | 27.4 | 28.0 | 28.7 | 32 |
| 34 | 21.9 | 22.5 | 23.1 | 23.7 | 24.4 | 25.0 | 25.6 | 26.2 | 26.9 | 27.5 | 28.1 | 28.7 | 29.4 | 34 |
| 36 | 22.5 | 23.1 | 23.7 | 24.4 | 25.0 | 25.7 | 26.3 | 26.9 | 27.6 | 28.2 | 28.9 | 29.5 | 30.2 | 36 |
| 38 | 23.1 | 23.7 | 24.4 | 25.1 | 25.7 | 26.4 | 27.1 | 27.7 | 28.4 | 29.1 | 29.7 | 30.4 | 31.1 | 38 |

Step 4: Answer required questions.

a) **Amplitude = E 25° N**
b) Standard sunrise is 090° T. In the northern hemisphere in spring and summer, the sun rises north of east (e.g. the declination is North). Therefore, the calculated sunrise is 090° - 25° = **065° T**
**c)** If the sun is observed rising at 068° T, while the calculated sunrise is 065° T, the gyro error is 068° - 065° = 3°. To determine the direction of error, use the mnemonic "Gyro Best, Error West, Gyro Least, Error East." In this case, the gyro is higher (best) than the observation, so the error is **3° W.**

AMP D2. On 24 August in DR position latitude 26° 49.4' N, longitude 146° 19.4' E, you observe an amplitude of the Sun. The Sun's center is on the celestial horizon and bears 084° psc. The chronometer reads 07h 55m 06s and is 01m 11s fast. Variation in the area is 15° W. What is the deviation of the magnetic compass?

Answer: 8.2° E deviation.

Step 1: Determine the actual time of observation.
07:55:06 chronometer time of observation
00:01:11 fast on GMT
07:55:06 – 00:01:11 = 07:53:55 correct chronometer time

146° 19.4’ E corresponds to a zone time of (-10). Since the approximate zone time is 07:53, the correct GMT is actually 19:53:55, on the 23rd of August.

Step 2: Determine the declination of the sun for the time of observation using the Nautical Almanac.

| G.M.T. | SUN G.H.A. | SUN Dec. |
|---|---|---|
| 18 | 89 22.5 | N11 17.8 |
| 19 | 104 22.6 | 17.0 |
| 20 | 119 22.8 | 16.1 |
| 21 | 134 23.0 | · · 15.3 |
| 22 | 149 23.1 | 14.4 |
| 23 | 164 23.3 | 13.6 |
| | S.D. 15.8 | *d* 0.9 |

The declination at 19:53:55 is not given in the Nautical Almanac and must be interpolated.

The base value for 1900 is N 11° 17.0’ and decreasing.
The *d* value for 23-25 August is 0.9.

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 53 minutes, 55 seconds (the difference between the base declination and the observation time).

| 53m | SUN PLANETS | ARIES | MOON | v or d | Corrn | v or d | Corrn | v or d | Corrn |
|---|---|---|---|---|---|---|---|---|---|
| s | ° ′ | ° ′ | ° ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| 00 | 13 15·0 | 13 17·2 | 12 38·8 | 0·0 | 0·0 | 6·0 | 5·4 | 12·0 | 10·7 |
| 01 | 13 15·3 | 13 17·4 | 12 39·0 | 0·1 | 0·1 | 6·1 | 5·4 | 12·1 | 10·8 |
| 02 | 13 15·5 | 13 17·7 | 12 39·3 | 0·2 | 0·2 | 6·2 | 5·5 | 12·2 | 10·9 |
| 03 | 13 15·8 | 13 17·9 | 12 39·5 | 0·3 | 0·3 | 6·3 | 5·6 | 12·3 | 11·0 |
| 04 | 13 16·0 | 13 18·2 | 12 39·7 | 0·4 | 0·4 | 6·4 | 5·7 | 12·4 | 11·1 |
| 05 | 13 16·3 | 13 18·4 | 12 40·0 | 0·5 | 0·4 | 6·5 | 5·8 | 12·5 | 11·1 |
| 06 | 13 16·5 | 13 18·7 | 12 40·2 | 0·6 | 0·5 | 6·6 | 5·9 | 12·6 | 11·2 |
| 07 | 13 16·8 | 13 18·9 | 12 40·5 | 0·7 | 0·6 | 6·7 | 6·0 | 12·7 | 11·3 |
| 08 | 13 17·0 | 13 19·2 | 12 40·7 | 0·8 | 0·7 | 6·8 | 6·1 | 12·8 | 11·4 |
| 09 | 13 17·3 | 13 19·4 | 12 40·9 | 0·9 | 0·8 | 6·9 | 6·2 | 12·9 | 11·5 |

Given a *d* value of 0.9, the declination correction factor is 0.8.

Since the declination is decreasing from hour to hour, the corrected declination for 24 August at 19:53:55 is N 11° 17.0’ – 0.8’= N 11° 16.2’

Step 3: Determine the ship’s latitude at the time of observation.
Latitude – 26° 49.4’ N (given)

Step 4: Enter Table 22/27 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: N 11° 16.2’ = N 11.3°
Latitude: 26° 49.4’ N = 26.8° N

| Amplitudes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | Declination | | | | | | | | | | | | | Latitude |
| | 6°0 | 6°5 | 7°0 | 7°5 | 8°0 | 8°5 | 9°0 | 9°5 | 10°0 | 10°5 | 11°0 | 11°5 | 12°0 | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 10.5 | 11.0 | 11.5 | 12.0 | 0 |
| 10 | 6.1 | 6.6 | 7.1 | 7.6 | 8.1 | 8.6 | 9.1 | 9.6 | 10.2 | 10.7 | 11.2 | 11.7 | 12.2 | 10 |
| 15 | 6.2 | 6.7 | 7.2 | 7.8 | 8.3 | 8.8 | 9.3 | 9.8 | 10.4 | 10.9 | 11.4 | 11.9 | 12.4 | 15 |
| 20 | 6.4 | 6.9 | 7.5 | 8.0 | 8.5 | 9.0 | 9.6 | 10.1 | 10.6 | 11.2 | 11.7 | 12.2 | 12.8 | 20 |
| 25 | 6.6 | 7.2 | 7.7 | 8.3 | 8.8 | 9.4 | 9.9 | 10.5 | 11.0 | 11.6 | 12.2 | 12.7 | 13.3 | 25 |
| 30 | 6.9 | 7.5 | 8.1 | 8.7 | 9.2 | 9.8 | 10.4 | 11.0 | 11.6 | 12.1 | 12.7 | 13.3 | 13.9 | 30 |
| 32 | 7.1 | 7.7 | 8.3 | 8.9 | 9.4 | 10.0 | 10.6 | 11.2 | 11.8 | 12.4 | 13.0 | 13.6 | 14.2 | 32 |
| 34 | 7.2 | 7.8 | 8.5 | 9.1 | 9.7 | 10.3 | 10.9 | 11.5 | 12.1 | 12.7 | 13.3 | 13.9 | 14.5 | 34 |
| 36 | 7.4 | 8.0 | 8.7 | 9.3 | 9.9 | 10.5 | 11.1 | 11.8 | 12.4 | 13.0 | 13.6 | 14.3 | 14.9 | 36 |
| 38 | 7.6 | 8.3 | 8.9 | 9.5 | 10.2 | 10.8 | 11.5 | 12.1 | 12.7 | 13.4 | 14.0 | 14.7 | 15.3 | 38 |

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required. Locate the bracketing values.

| | Declination 11.0° | **Declination 11.3°** | Declination 11.5° |
|---|---|---|---|
| Latitude 25° | 12.2° | | 12.7° |
| **Latitude 26.8°** | | **Unknown value** | |
| Latitude 30° | 12.7° | | 13.3° |

b) Interpolate the bracketing values four ways to the nearest tenth.

| | Declination 10.5° | **Declination 10.9°** | Declination 11° |
|---|---|---|---|
| Latitude 25° | 12.2° | **12.6°** | 12.7° |
| **Latitude 26.8°** | **12.4°** | **Unknown value** | **12.9°** |
| Latitude 30° | 12.7° | **13.2°** | 13.3° |

c) Solve the interpolation for the desired value.

| | Declination 10.5° | **Declination 10.9°** | Declination 11° |
|---|---|---|---|
| Latitude 25° | 12.2° | 12.6° | 12.7° |
| **Latitude 26.8°** | 12.4° | **12.8°** | 12.9° |
| Latitude 30° | 12.7° | 13.2° | 13.3° |

**Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22/27 explanation.*

$$\sin(Amplitude) = \sec(Latitude) \times \sin(Declination)$$

*-or –*

$$\sin(Amplitude) = \frac{\sin(Declination)}{\cos\,(Latitude)}$$

Step 5: Answer required questions.

Since the calculated amplitude is 12.8°, the sun is rising, and the season is summer in the northern hemisphere (e.g. the declination of the body is north), the correct notation for the amplitude is E 12.8° N, and the calculated compass bearing to sunrise should be:

090° - 12.8° = 77.2° T

Therefore, using a compass correction formula, the deviation of the compass is calculated as:

T: 77.2° T (Bearing to sunrise)
V: 15° W (Given)
M: 092.2° (Calculated)
D:
C: 084° psc (Given)

**Deviation = 8.2° E**

# Amplitude Problems

## Amplitude Problems of the Sun on the Visible Horizon

AMP D3. It is 18 August. You have taken an observation of the rising sun when its center is on the visible horizon. The time of observation is 1500 UTC. Your latitude is 52° N.

a) What is the amplitude of the sun?
b) What true bearing should the sunrise be observed?
c) If you actually observe the sun rising at 065° pgc, what is the gyro error?

Answers:
a) Amplitude: E 21.4° N
b) True bearing: 068.6° T
c) Gyro error: 2.6° E

| G.M.T. | SUN | |
|---|---|---|
| | G.H.A. | Dec. |
| 12 | 359 03.3 | N13 02.5 |
| 13 | 14 03.4 | 01.7 |
| 14 | 29 03.6 | 00.8 |
| 15 | 44 03.7 | 13 00.0 |
| 16 | 59 03.8 | 12 59.2 |
| 17 | 74 04.0 | 58.4 |

Step 1: Determine the declination of the sun for the time of observation using the Nautical Almanac.
The declination at 1500 UTC is N 13° 00'.

Step 2: Determine the ship's latitude at the time of observation.
Latitude – 52° N (given)

Step 3: Enter Table 23/28 in Bowditch with declination and latitude to determine a correction due to the object's location on the visible horizon.

Correction of Amplitude as Observed on the Visible Horizon

| Declination | | | | | | | | | | | | | Latitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0° | 2° | 4° | 6° | 8° | 10° | 12° | 14° | 16° | 18° | 20° | 22° | 24° | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| 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 | 10 |
| 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 15 |
| 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 20 |
| 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 25 |
| 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 30 |
| 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 32 |
| 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 34 |
| 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.6 | 0.6 | 0.6 | 36 |
| 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 38 |
| 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 40 |
| 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 42 |
| 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 44 |
| 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 46 |
| 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 48 |
| 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.0 | 1.1 | 1.0 | 50 |
| 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.1 | 1.1 | 1.1 | 51 |
| 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.3 | 52 |
| 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 | 1.1 | 1.2 | 1.2 | 1.3 | 53 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 54 |

The correction is 1.0° (interpolated between the tabular values for 12° and 14° declination).

Step 4: Enter Table 22/27 in Bowditch with declination and latitude to determine the amplitude.
Declination: 13°
Latitude: 52°

Amplitudes

| Latitude | Declination | | | | | | | | | | | | | Latitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12°.0 | 12°.5 | 13°.0 | 13°.5 | 14°.0 | 14°.5 | 15°.0 | 15°.5 | 16°.0 | 16°.5 | 17°.0 | 17°.5 | 18°.0 | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0 | 12.0 | 12.5 | 13.0 | 13.5 | 14.0 | 14.5 | 15.0 | 15.5 | 16.0 | 16.5 | 17.0 | 17.5 | 18.0 | 0 |
| 10 | 12.2 | 12.7 | 13.2 | 13.7 | 14.2 | 14.7 | 15.2 | 15.7 | 16.3 | 16.8 | 17.3 | 17.8 | 18.3 | 10 |
| 15 | 12.4 | 12.9 | 13.5 | 14.0 | 14.5 | 15.0 | 15.5 | 16.1 | 16.6 | 17.1 | 17.6 | 18.1 | 18.7 | 15 |
| 20 | 12.8 | 13.3 | 13.9 | 14.4 | 14.9 | 15.5 | 16.0 | 16.5 | 17.1 | 17.6 | 18.1 | 18.7 | 19.2 | 20 |
| 25 | 13.3 | 13.8 | 14.4 | 14.9 | 15.5 | 16.0 | 16.6 | 17.1 | 17.7 | 18.3 | 18.8 | 19.4 | 19.9 | 25 |
| 30 | 13.9 | 14.5 | 15.1 | 15.6 | 16.2 | 16.8 | 17.4 | 18.0 | 18.6 | 19.1 | 19.7 | 20.3 | 20.9 | 30 |
| 32 | 14.2 | 14.8 | 15.4 | 16.0 | 16.6 | 17.2 | 17.8 | 18.4 | 19.0 | 19.6 | 20.2 | 20.8 | 21.4 | 32 |
| 34 | 14.5 | 15.1 | 15.7 | 16.4 | 17.0 | 17.6 | 18.2 | 18.8 | 19.4 | 20.0 | 20.7 | 21.3 | 21.9 | 34 |
| 36 | 14.9 | 15.5 | 16.1 | 16.8 | 17.4 | 18.0 | 18.7 | 19.3 | 19.9 | 20.6 | 21.2 | 21.8 | 22.5 | 36 |
| 38 | 15.3 | 15.9 | 16.6 | 17.2 | 17.9 | 18.5 | 19.2 | 19.8 | 20.5 | 21.1 | 21.8 | 22.4 | 23.1 | 38 |
| 40 | 15.7 | 16.4 | 17.1 | 17.7 | 18.4 | 19.1 | 19.7 | 20.4 | 21.1 | 21.8 | 22.4 | 23.1 | 23.8 | 40 |
| 41 | 16.0 | 16.7 | 17.3 | 18.0 | 18.7 | 19.4 | 20.1 | 20.8 | 21.4 | 22.1 | 22.8 | 23.5 | 24.2 | 41 |
| 42 | 16.2 | 16.9 | 17.6 | 18.3 | 19.0 | 19.7 | 20.4 | 21.1 | 21.8 | 22.5 | 23.2 | 23.9 | 24.6 | 42 |
| 43 | 16.5 | 17.2 | 17.9 | 18.6 | 19.3 | 20.0 | 20.7 | 21.4 | 22.1 | 22.9 | 23.6 | 24.3 | 25.0 | 43 |
| 44 | 16.8 | 17.5 | 18.2 | 18.9 | 19.7 | 20.4 | 21.1 | 21.8 | 22.5 | 23.3 | 24.0 | 24.7 | 25.4 | 44 |
| 45 | 17.1 | 17.8 | 18.5 | 19.3 | 20.0 | 20.7 | 21.5 | 22.2 | 22.9 | 23.7 | 24.4 | 25.2 | 25.9 | 45 |
| 46 | 17.4 | 18.2 | 18.9 | 19.6 | 20.4 | 21.1 | 21.9 | 22.6 | 23.4 | 24.1 | 24.9 | 25.7 | 26.4 | 46 |
| 47 | 17.7 | 18.5 | 19.3 | 20.0 | 20.8 | 21.5 | 22.3 | 23.1 | 23.8 | 24.6 | 25.4 | 26.2 | 26.9 | 47 |
| 48 | 18.1 | 18.9 | 19.6 | 20.4 | 21.2 | 22.0 | 22.8 | 23.5 | 24.3 | 25.1 | 25.9 | 26.7 | 27.5 | 48 |
| 49 | 18.5 | 19.3 | 20.1 | 20.8 | 21.6 | 22.4 | 23.2 | 24.0 | 24.8 | 25.7 | 26.5 | 27.3 | 28.1 | 49 |
| 50 | 18.9 | 19.7 | 20.5 | 21.3 | 22.1 | 22.9 | 23.7 | 24.6 | 25.4 | 26.2 | 27.1 | 27.9 | 28.7 | 50 |
| 51 | 19.3 | 20.1 | 20.9 | 21.8 | 22.6 | 23.4 | 24.3 | 25.1 | 26.0 | 26.8 | 27.7 | 28.5 | 29.4 | 51 |
| 52 | 19.7 | 20.6 | 21.4 | 22.3 | 23.1 | 24.0 | 24.9 | 25.7 | 26.6 | 27.5 | 28.3 | 29.2 | 30.1 | 52 |
| 53 | 20.2 | 21.1 | 21.9 | 22.8 | 23.7 | 24.6 | 25.5 | 26.4 | 27.3 | 28.2 | 29.1 | 30.0 | 30.9 | 53 |
| 54 | 20.7 | 21.6 | 22.5 | 23.4 | 24.3 | 25.2 | 26.1 | 27.0 | 28.0 | 28.9 | 29.8 | 30.8 | 31.7 | 54 |

a) This yields an amplitude of 21.4° or (E 21.4° N).

Step 5: Answer required questions.

a) Due to the object being on the visible horizon, the observation must be corrected.
   - Correction from Table 23/28 = 1.0°
   - The correction must be applied to the observation (not the amplitude) *away from the elevated (nearest) pole.*
   - In this case, the ship is in the northern hemisphere, so the elevated pole is north. The initial observation is 065° pgc.
   - The corrected observation is 065° pgc + 1.0° = 066° pgc.

b) Standard sunrise is 090° T. In the northern hemisphere in spring and summer, the sun rises north of east. Therefore, using the amplitude (E 21.4° N) the calculated sunrise is 090° - 21.4° = **68.6° T**

c) If the sun (corrected) is observed rising at 066° pgc, while the calculated sunrise is 68.6° T, the gyro error is 68.6° - 66° = 2.6°.

d) To determine the direction of error, use the mnemonic "Gyro Best, Error West, Gyro Least, Error East." In this case, the gyro is lower (least) than the observation, so the error is **2.6° E.**

## Amplitude Problems

AMP D4. On 11 May, in DR position latitude 37° 06.0’ N, longitude 45° 45.0’ W, you observe an amplitude of the Sun. The Sun’s center is on the visible horizon and bears 089° psc. The chronometer reads 07h 57m 06s and is 1m 48s slow. Variation is 20.0° W. What is the deviation?

Answer: 2.3° W deviation.

Step 1: Determine the actual time of observation.
07:57:06 chronometer time of observation
00:01:48 slow on GMT
07:57:06 + 00:01:48 = 07:58:54 correct chronometer time

45° 45.0’ W corresponds to a zone time of (+3) and the correct GMT is 07:58:54.

Step 2: Determine the declination of the sun for the time of observation using the Nautical Almanac.

| G.M.T. | SUN G.H.A. | SUN Dec. |
|---|---|---|
| 06 | 270 55.2 | N17 51.8 |
| 07 | 285 55.2 | 52.5 |
| 08 | 300 55.2 | 53.1 |
| | S.D. 15.9 | *d* 0.6 |

The declination at 07:58:54 is not given in the Nautical Almanac and must be interpolated.

The base value for 0700 is N 17° 52.5’ and increasing.
The d value for 10-12 May is 0.6.

Enter the Increments and Corrections Page in the Nautical Almanac with the daily d value and a time of 58 minutes (the difference between the base declination and the observation time).

| 58m s | SUN PLANETS ° ′ | ARIES ° ′ | MOON ° ′ | v or d ′ | Corr^n ′ | v or d ′ | Corr^n ′ | v or d ′ | Corr^n ′ |
|---|---|---|---|---|---|---|---|---|---|
| 00 | 14 30·0 | 14 32·4 | 13 50·4 | 0·0 | 0·0 | 6·0 | 5·9 | 12·0 | 11·7 |
| 01 | 14 30·3 | 14 32·6 | 13 50·6 | 0·1 | 0·1 | 6·1 | 5·9 | 12·1 | 11·8 |
| 02 | 14 30·5 | 14 32·9 | 13 50·8 | 0·2 | 0·2 | 6·2 | 6·0 | 12·2 | 11·9 |
| 03 | 14 30·8 | 14 33·1 | 13 51·1 | 0·3 | 0·3 | 6·3 | 6·1 | 12·3 | 12·0 |
| 04 | 14 31·0 | 14 33·4 | 13 51·3 | 0·4 | 0·4 | 6·4 | 6·2 | 12·4 | 12·1 |
| 05 | 14 31·3 | 14 33·6 | 13 51·6 | 0·5 | 0·5 | 6·5 | 6·3 | 12·5 | 12·2 |
| 06 | 14 31·5 | 14 33·9 | 13 51·8 | 0·6 | 0·6 | 6·6 | 6·4 | 12·6 | 12·3 |
| 07 | 14 31·8 | 14 34·1 | 13 52·0 | 0·7 | 0·7 | 6·7 | 6·5 | 12·7 | 12·4 |
| 08 | 14 32·0 | 14 34·4 | 13 52·3 | 0·8 | 0·8 | 6·8 | 6·6 | 12·8 | 12·5 |
| 09 | 14 32·3 | 14 34·6 | 13 52·5 | 0·9 | 0·9 | 6·9 | 6·7 | 12·9 | 12·6 |

Given a d value of 0.6, the declination correction factor is 0.6.

Since the declination is increasing from hour to hour, the corrected declination for 11 May at 07:58:54 is N 17° 52.5’ + 0.6’= <u>N 17° 53.1’</u>

Step 3: Determine the ship’s latitude at the time of observation.
Latitude – 37° 06’ N (given)

Step 4: Since the body is observed on the visible horizon, enter Table 23/28 in Bowditch to obtain the Visible Horizon Correction.

| Correction of Amplitude as Observed on the Visible Horizon | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Declination | | | | | | | | | | | | | Latitude |
| 0° | 2° | 4° | 6° | 8° | 10° | 12° | 14° | 16° | 18° | 20° | 22° | 24° | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0 |
| 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 | 10 |
| 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 15 |
| 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 20 |
| 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 4 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 25 |
| 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 5 | 30 |
| 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 5 | 0. 5 | 32 |
| 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 34 |
| 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 6 | 0. 5 | 0. 6 | 0. 6 | 0. 6 | 36 |
| 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 38 |

By visual inspection, the correction is 0.6°.

Per the instructions at the bottom of the table, for the Sun, the correction is always applied away from the elevated pole and it is applied to the observed bearing and not to the Amplitude. Since the observer is in the northern hemisphere, the north pole is the elevated pole. Since the Sun is rising, the correction should be added.

Observed: 089° psc
Table 23/28 Correction: + 0.6°
Total: 089° + 0.6° = 089.6° psc

Step 5: Enter Table 22/27 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: N 17° 53.1'= N 17.9°
Latitude: 37° 06.0' N = 37.1° N

| Amplitudes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | Declination | | | | | | | | | | | | | Latitude |
| | 12°.0 | 12°.5 | 13°.0 | 13°.5 | 14°.0 | 14°.5 | 15°.0 | 15°.5 | 16°.0 | 16°.5 | 17°.0 | 17°.5 | 18°.0 | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0 | 12. 0 | 12. 5 | 13. 0 | 13. 5 | 14. 0 | 14. 5 | 15. 0 | 15. 5 | 16. 0 | 16. 5 | 17. 0 | 17. 5 | 18. 0 | 0 |
| 10 | 12. 2 | 12. 7 | 13. 2 | 13. 7 | 14. 2 | 14. 7 | 15. 2 | 15. 7 | 16. 3 | 16. 8 | 17. 3 | 17. 8 | 18. 3 | 10 |
| 15 | 12. 4 | 12. 9 | 13. 5 | 14. 0 | 14. 5 | 15. 0 | 15. 5 | 16. 1 | 16. 6 | 17. 1 | 17. 6 | 18. 1 | 18. 7 | 15 |
| 20 | 12. 8 | 13. 3 | 13. 9 | 14. 4 | 14. 9 | 15. 5 | 16. 0 | 16. 5 | 17. 1 | 17. 6 | 18. 1 | 18. 7 | 19. 2 | 20 |
| 25 | 13. 3 | 13. 8 | 14. 4 | 14. 9 | 15. 5 | 16. 0 | 16. 6 | 17. 1 | 17. 7 | 18. 3 | 18. 8 | 19. 4 | 19. 9 | 25 |
| 30 | 13. 9 | 14. 5 | 15. 1 | 15. 6 | 16. 2 | 16. 8 | 17. 4 | 18. 0 | 18. 6 | 19. 1 | 19. 7 | 20. 3 | 20. 9 | 30 |
| 32 | 14. 2 | 14. 8 | 15. 4 | 16. 0 | 16. 6 | 17. 2 | 17. 8 | 18. 4 | 19. 0 | 19. 6 | 20. 2 | 20. 8 | 21. 4 | 32 |
| 34 | 14. 5 | 15. 1 | 15. 7 | 16. 4 | 17. 0 | 17. 6 | 18. 2 | 18. 8 | 19. 4 | 20. 0 | 20. 7 | 21. 3 | 21. 9 | 34 |
| 36 | 14. 9 | 15. 5 | 16. 1 | 16. 8 | 17. 4 | 18. 0 | 18. 7 | 19. 3 | 19. 9 | 20. 6 | 21. 2 | 21. 8 | 22. 5 | 36 |
| 38 | 15. 3 | 15. 9 | 16. 6 | 17. 2 | 17. 9 | 18. 5 | 19. 2 | 19. 8 | 20. 5 | 21. 1 | 21. 8 | 22. 4 | 23. 1 | 38 |

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required. Locate the bracketing values.

| | |
|---|---|
| 21.8 | 22.5 |
| 22.4 | 23.1 |

| | Declination 17.5° | **Declination 17.9°** | Declination 18.0° |
|---|---|---|---|
| Latitude 36° | 21.8° | | 22.5° |
| **Latitude 37.1°** | | **Unknown value** | |
| Latitude 38° | 22.4° | | 23.1° |

b) Interpolate the bracketing values four ways to the nearest tenth.

| | Declination 17.5° | **Declination 17.9°** | Declination 18.0° |
|---|---|---|---|
| Latitude 36° | 21.8° | **22.4°** | 22.5° |
| **Latitude 37.1°** | **22.0°** | **Unknown value** | **22.6°** |
| Latitude 38° | 22.4° | **23.0°** | 23.1° |

c) Solve the final interpolation for the desired value.

| | Declination 17.5° | **Declination 17.9°** | Declination 18.0° |
|---|---|---|---|
| Latitude 36° | 21.8° | 22.4° | 22.5° |
| **Latitude 37.1°** | 22.0° | **22.7°** | 22.6° |
| Latitude 38° | 22.4° | 23.0° | 23.1° |

*Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22/27 explanation.

$$\sin(\text{Amplitude}) = \sec(\text{Latitude}) \times \sin(\text{Declination})$$

-or –

$$\sin(\text{Amplitude}) = \left(\frac{\sin(\text{Declination})}{\cos(\text{Latitude})}\right)$$

Step 6: Answer required questions.

Since the calculated amplitude is 22.7°, the sun is rising, and the season is spring in the northern hemisphere, the correct notation for the amplitude is E 22.7° N, and the calculated compass bearing to sunrise should be:
090° - 22.7° = 67.3° T

Therefore, using a compass correction formula, the deviation of the compass is calculated as:
T: 67.3° T (Bearing to sunrise)
V: 20° W (Given)
M: 087.3° (Calculated)
D:
C: 089.6° psc (Given and then corrected for visible horizon using Table 23/28)

**Deviation = 2.3° W**

Amplitude Problems of the Moon

- Celestial Horizon: Moon amplitude problems are calculated exactly like Sun problems when the moon is on the celestial horizon (e.g. when the upper limb is on the visible horizon).

- Visible Horizon: When the Moon's center is on the visible horizon, a correction is required. Moon amplitude problems are calculated differently than Sun problems when a Table 23/28 correction is required. Instead of the correction being applied away from the elevated pole (like the sun), the correction is applied such that half of the value is applied toward the elevated pole.

AMP D5. At 1524 ZT on 14 June in DR position latitude 30° 51' N, longitude 30° 02' W, you observe an amplitude of the Moon. The center of the Moon is on the visible horizon and bears 103.9 pgc. The variation is 10° W. What is the gyro error?

Answer: 2.0° E.

| G.M.T. | SUN G.H.A. | SUN Dec. | MOON G.H.A. | MOON *v* | MOON Dec. | MOON *d* | MOON H.P. |
|---|---|---|---|---|---|---|---|
| 12 | 359 57.5 | N23 16.3 | 214 55.5 | 14.4 | S12 40.0 | 8.6 | 54.0 |
| 13 | 14 57.4 | 16.5 | 229 28.9 | 14.5 | 12 48.6 | 8.6 | 54.0 |
| 14 | 29 57.2 | 16.6 | 244 02.4 | 14.3 | 12 57.2 | 8.5 | 54.1 |
| 15 | 44 57.1 | · · 16.7 | 258 35.7 | 14.4 | 13 05.7 | 8.5 | 54.1 |
| 16 | 59 57.0 | 16.8 | 273 09.1 | 14.3 | 13 14.2 | 8.4 | 54.1 |
| 17 | 74 56.8 | 16.9 | 287 42.4 | 14.2 | 13 22.6 | 8.4 | 54.1 |

Step 1: Determine the actual time of observation.
1524 chronometer time of observation

30° 02' W corresponds to a zone time of (+2), and the correct GMT is 1724.

Step 2: Determine the declination of the Moon for the time of observation using the Nautical Almanac.

The declination at 1724 is not given in the Nautical Almanac and must be interpolated.

The base value for 1700 is S 13° 22.6' and increasing.
The *d* value for the hour is 14.7.

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 24 minutes (the difference between the base declination and the observation time).

Given a *d* value of 14.7 the declination correction is 6.0'.

Since the declination is increasing from hour to hour, the corrected declination for 14 June at 1724 is S 13° 22.6' + 6.0'= <u>S 13° 28.6'</u>

Step 3: Determine the ship's latitude at the time of observation.
Latitude – 30° 51' N (given)

Step 4: Since the body is observed on the visible horizon, enter Table 23/28 in Bowditch to obtain the Visible Horizon Correction for the Moon.

| Correction of Amplitude as Observed on the Visible Horizon | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Declination | | | | | | | | | | | | | Latitude |
| 0° | 2° | 4° | 6° | 8° | 10° | 12° | 14° | 16° | 18° | 20° | 22° | 24° | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0. 0 | 0 |
| 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 | 10 |
| 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 0. 2 | 15 |
| 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 20 |
| 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 4 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 0. 3 | 25 |
| 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 5 | 30 |
| 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 4 | 0. 5 | 0. 5 | 0. 5 | 32 |
| 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 34 |
| 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 5 | 0. 6 | 0. 5 | 0. 6 | 0. 6 | 0. 6 | 36 |
| 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 0. 6 | 38 |

By visual inspection, the correction is 0.4°.

Per the instructions at the bottom of the table, for the Moon, the correction is always divided in 2 and applied toward the elevated pole. Since the observer is in the northern hemisphere, the north pole is the elevated pole. Since the Moon is rising, the correction should be subtracted.

Observed: 103.9° pgc
Table 23 Correction: - 0.2°
Total: 103.9° - 0.2° = <u>103.7° pgc</u>

Step 5: Enter Table 22/27 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: S 13° 26.0'= N 13.4°
Latitude: 30° 51' N = 30.9° N

| Amplitudes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Latitude | Declination | | | | | | | | | | | | | Latitude |
| | 12°.0 | 12°.5 | 13°.0 | 13°.5 | 14°.0 | 14°.5 | 15°.0 | 15°.5 | 16°.0 | 16°.5 | 17°.0 | 17°.5 | 18°.0 | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0 | 12. 0 | 12. 5 | 13. 0 | 13. 5 | 14. 0 | 14. 5 | 15. 0 | 15. 5 | 16. 0 | 16. 5 | 17. 0 | 17. 5 | 18. 0 | 0 |
| 10 | 12. 2 | 12. 7 | 13. 2 | 13. 7 | 14. 2 | 14. 7 | 15. 2 | 15. 7 | 16. 3 | 16. 8 | 17. 3 | 17. 8 | 18. 3 | 10 |
| 15 | 12. 4 | 12. 9 | 13. 5 | 14. 0 | 14. 5 | 15. 0 | 15. 5 | 16. 1 | 16. 6 | 17. 1 | 17. 6 | 18. 1 | 18. 7 | 15 |
| 20 | 12. 8 | 13. 3 | 13. 9 | 14. 4 | 14. 9 | 15. 5 | 16. 0 | 16. 5 | 17. 1 | 17. 6 | 18. 1 | 18. 7 | 19. 2 | 20 |
| 25 | 13. 3 | 13. 8 | 14. 4 | 14. 9 | 15. 5 | 16. 0 | 16. 6 | 17. 1 | 17. 7 | 18. 3 | 18. 8 | 19. 4 | 19. 9 | 25 |
| 30 | 13. 9 | 14. 5 | 15. 1 | 15. 6 | 16. 2 | 16. 8 | 17. 4 | 18. 0 | 18. 6 | 19. 1 | 19. 7 | 20. 3 | 20. 9 | 30 |
| 32 | 14. 2 | 14. 8 | 15. 4 | 16. 0 | 16. 6 | 17. 2 | 17. 8 | 18. 4 | 19. 0 | 19. 6 | 20. 2 | 20. 8 | 21. 4 | 32 |
| 34 | 14. 5 | 15. 1 | 15. 7 | 16. 4 | 17. 0 | 17. 6 | 18. 2 | 18. 8 | 19. 4 | 20. 0 | 20. 7 | 21. 3 | 21. 9 | 34 |
| 36 | 14. 9 | 15. 5 | 16. 1 | 16. 8 | 17. 4 | 18. 0 | 18. 7 | 19. 3 | 19. 9 | 20. 6 | 21. 2 | 21. 8 | 22. 5 | 36 |
| 38 | 15. 3 | 15. 9 | 16. 6 | 17. 2 | 17. 9 | 18. 5 | 19. 2 | 19. 8 | 20. 5 | 21. 1 | 21. 8 | 22. 4 | 23. 1 | 38 |

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required. Locate the bracketing values.

| | |
|---|---|
| 15.1 | 15.6 |
| 15.4 | 16.0 |

| | Declination 13.0° | **Declination 13.4°** | Declination 13.5° |
|---|---|---|---|
| Latitude 30° | 15.1° | | 15.6° |
| **Latitude 30.9°** | | **Unknown value** | |
| Latitude 32° | 15.4° | | 16.0° |

b) Interpolate the bracketing values four ways to the nearest tenth.

| | Declination 13.0° | **Declination 13.4°** | Declination 13.5° |
|---|---|---|---|
| Latitude 30° | 15.1° | **15.5°** | 15.6° |
| **Latitude 30.9°** | **15.2°** | **Unknown value** | **15.8°** |
| Latitude 32° | 15.4° | **15.9°** | 16.0° |

c) Solve the interpolation for the desired value.

| | Declination 13.0° | **Declination 13.4°** | Declination 13.5° |
|---|---|---|---|
| Latitude 30° | 15.1° | 15.5° | 15.6° |
| **Latitude 30.9°** | 15.2° | **15.7°** | 15.8° |
| Latitude 32° | 15.4° | 15.9° | 16.0° |

**Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22 explanation.*

$$\sin(Amplitude) = \sec(Latitude) \times \sin(Declination)$$

*-or –*

$$\sin(Amplitude) = \left(\frac{\sin(Declination)}{\cos(Latitude)}\right)$$

Step 6: Answer required questions.

Since the calculated amplitude is 15.7°, the Moon is rising, and the declination is south, the correct notation for the amplitude is E 15.7° S, and the calculated compass bearing to moonrise should be:

090° + 15.7° = 105.7° T

Therefore, using a gyro error calculation, the gyro error is:
G: 103.7° pgc (Given)
E:
T: 105.7° T (Calculated)

**Gyro Error = 2.0° E**

Amplitude Problems

## Amplitude Problems of Planets

- Amplitudes of Planets are completed in the same manner as those for the sun. Planets are on the celestial horizon when they are approximately one sun diameter above the visible horizon.

AMP D6. At 2043 ZT on 13 October in DR position latitude 43° 57.3' S, longitude 147° 16.0' E, you observe an amplitude of Venus. The planet is about one sun's diameter above the horizon and bears 236.2° pgc. The variation is 15° E. What is the gyro error?

Answer: 0.0°.

Step 1: Determine the actual time of observation.
2043 chronometer time of observation

147° 16.0' E corresponds to a zone time of (-10), and the correct GMT is 1043 on 13 October.

Step 2: Determine the declination of the planet for the time of observation using the Nautical Almanac.

The declination at 1043 is not given in the Nautical Almanac and must be interpolated.

The base value for 1000 is S 23° 36.3' and increasing.
The *d* value for 13 October is 0.6.

| G.M.T. | ARIES G.H.A. | VENUS −3.8 G.H.A. | Dec. |
|---|---|---|---|
| 06 | 111 42.7 | 229 23.3 | S23 33.7 |
| 07 | 126 45.2 | 244 22.8 | 34.3 |
| 08 | 141 47.7 | 259 22.3 | 35.0 |
| 09 | 156 50.1 | 274 21.8 | · · 35.6 |
| 10 | 171 52.6 | 289 21.3 | 36.3 |
| 11 | 186 55.1 | 304 20.8 | 36.9 |
| Mer. Pass. | h m 22 26.5 | *v* −0.5 | *d* 0.6 |

| 43m | SUN PLANETS | ARIES | MOON | *v* or *d* | Corrⁿ | *v* or *d* | Corrⁿ | *v* or *d* | Corrⁿ |
|---|---|---|---|---|---|---|---|---|---|
| s | ° ' | ° ' | ° ' | ' | ' | ' | ' | ' | ' |
| 00 | 10 45·0 | 10 46·8 | 10 15·6 | 0·0 | 0·0 | 6·0 | 4·4 | 12·0 | 8·7 |
| 01 | 10 45·3 | 10 47·0 | 10 15·9 | 0·1 | 0·1 | 6·1 | 4·4 | 12·1 | 8·8 |
| 02 | 10 45·5 | 10 47·3 | 10 16·1 | 0·2 | 0·1 | 6·2 | 4·5 | 12·2 | 8·8 |
| 03 | 10 45·8 | 10 47·5 | 10 16·3 | 0·3 | 0·2 | 6·3 | 4·6 | 12·3 | 8·9 |
| 04 | 10 46·0 | 10 47·8 | 10 16·6 | 0·4 | 0·3 | 6·4 | 4·6 | 12·4 | 9·0 |
| 05 | 10 46·3 | 10 48·0 | 10 16·8 | 0·5 | 0·4 | 6·5 | 4·7 | 12·5 | 9·1 |
| 06 | 10 46·5 | 10 48·3 | 10 17·0 | 0·6 | 0·4 | 6·6 | 4·8 | 12·6 | 9·1 |
| 07 | 10 46·8 | 10 48·5 | 10 17·3 | 0·7 | 0·5 | 6·7 | 4·9 | 12·7 | 9·2 |
| 08 | 10 47·0 | 10 48·8 | 10 17·5 | 0·8 | 0·6 | 6·8 | 4·9 | 12·8 | 9·3 |
| 09 | 10 47·3 | 10 49·0 | 10 17·8 | 0·9 | 0·7 | 6·9 | 5·0 | 12·9 | 9·4 |

Enter the Increments and Corrections Page in the Nautical Almanac with the daily *d* value and a time of 43 minutes (the difference between the base declination and the observation time).

Given a *d* value of 0.6 the declination correction is 0.4'.

Since the declination is increasing from hour to hour, the corrected declination for 13 October at 1043 is S 23° 36.3' + 0.4'= S 23° 36.7'

Step 3: Determine the ship's latitude at the time of observation.
Latitude – 43° 57.3' S (given)

Step 4: Enter Table 22 in Bowditch with declination (in tenths notation) and latitude to determine the amplitude.
Declination: S 23° 36.7'= S 23.6°
Latitude: 43° 57.3' S = 43.96° S

a) Since the entering values are not whole numbers of declination or latitude, interpolation is required.

| Latitude | Declination | | | | | | | | | | | | | Latitude |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18°.0 | 18°.5 | 19°.0 | 19°.5 | 20°.0 | 20°.5 | 21°.0 | 21°.5 | 22°.0 | 22°.5 | 23°.0 | 23°.5 | 24°.0 | |
| ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 0 | 18.0 | 18.5 | 19.0 | 19.5 | 20.0 | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | 0 |
| 10 | 18.3 | 18.8 | 19.3 | 19.8 | 20.3 | 20.8 | 21.3 | 21.8 | 22.4 | 22.9 | 23.4 | 23.9 | 24.4 | 10 |
| 15 | 18.7 | 19.2 | 19.7 | 20.2 | 20.7 | 21.3 | 21.8 | 22.3 | 22.8 | 23.3 | 23.9 | 24.4 | 24.9 | 15 |
| 20 | 19.2 | 19.7 | 20.3 | 20.8 | 21.3 | 21.9 | 22.4 | 23.0 | 23.5 | 24.0 | 24.6 | 25.1 | 25.6 | 20 |
| 25 | 19.9 | 20.5 | 21.1 | 21.6 | 22.2 | 22.7 | 23.3 | 23.9 | 24.4 | 25.0 | 25.5 | 26.1 | 26.7 | 25 |
| 30 | 20.9 | 21.5 | 22.1 | 22.7 | 23.3 | 23.9 | 24.4 | 25.0 | 25.6 | 26.2 | 26.8 | 27.4 | 28.0 | 30 |
| 32 | 21.4 | 22.0 | 22.6 | 23.2 | 23.8 | 24.4 | 25.0 | 25.6 | 26.2 | 26.8 | 27.4 | 28.0 | 28.7 | 32 |
| 34 | 21.9 | 22.5 | 23.1 | 23.7 | 24.4 | 25.0 | 25.6 | 26.2 | 26.9 | 27.5 | 28.1 | 28.7 | 29.4 | 34 |
| 36 | 22.5 | 23.1 | 23.7 | 24.4 | 25.0 | 25.7 | 26.3 | 26.9 | 27.6 | 28.2 | 28.9 | 29.5 | 30.2 | 36 |
| 38 | 23.1 | 23.7 | 24.4 | 25.1 | 25.7 | 26.4 | 27.1 | 27.7 | 28.4 | 29.1 | 29.7 | 30.4 | 31.1 | 38 |
| 40 | 23.8 | 24.5 | 25.2 | 25.8 | 26.5 | 27.2 | 27.9 | 28.6 | 29.3 | 30.0 | 30.7 | 31.4 | 32.1 | 40 |
| 41 | 24.2 | 24.9 | 25.6 | 26.3 | 26.9 | 27.6 | 28.3 | 29.1 | 29.8 | 30.5 | 31.2 | 31.9 | 32.6 | 41 |
| 42 | 24.6 | 25.3 | 26.0 | 26.7 | 27.4 | 28.1 | 28.8 | 29.5 | 30.3 | 31.0 | 31.7 | 32.5 | 33.2 | 42 |
| 43 | 25.0 | 25.7 | 26.4 | 27.2 | 27.9 | 28.6 | 29.3 | 30.1 | 30.8 | 31.6 | 32.3 | 33.0 | 33.8 | 43 |
| 44 | 25.4 | 26.2 | 26.9 | 27.6 | 28.4 | 29.1 | 29.9 | 30.6 | 31.4 | 32.1 | 32.9 | 33.7 | 34.4 | 44 |

b) Locate the bracketing values.

| | |
|---|---|
| 33.0 | 33.8 |
| 33.7 | 34.4 |

| | Declination 23.5° | **Declination 23.6°** | Declination 24° |
|---|---|---|---|
| Latitude 43° | 33.0° | | 33.8° |
| **Latitude 43.95°** | | **Unknown value** | |
| Latitude 44° | 33.7° | | 34.4° |

c) Interpolate the bracketing values four ways to the nearest tenth.

| | Declination 23.5° | **Declination 23.6°** | Declination 24° |
|---|---|---|---|
| Latitude 43° | 33.0° | **33.2°** | 33.8° |
| **Latitude 43.95°** | **33.7°** | **Unknown value** | **34.4°** |
| Latitude 44° | 33.7° | **33.8°** | 34.4° |

d) Solve the interpolation for the desired value.

| | Declination 23.5° | **Declination 23.6°** | Declination 24° |
|---|---|---|---|
| Latitude 43° | 33.0° | 33.2° | 33.8° |
| **Latitude 43.95°** | 33.7° | **33.8°** | 34.4° |
| Latitude 44° | 33.7° | 33.8° | 34.4° |

**Note that the amplitude can also be solved directly using the instructions in the Bowditch table 22 explanation.*

$$\sin(Amplitude) = \sec(Latitude) \times \sin(Declination)$$

*-or –*

$$\sin(Amplitude) = \left(\frac{\sin(Declination)}{\cos(Latitude)}\right)$$

Step 5: Answer required questions.

Since the calculated amplitude is 33.8°, the planet is setting, and the declination is south, the correct notation for the amplitude is W 33.8° S, and the calculated compass bearing to planet-set should be:

270° - 33.8° = 236.2° T

Therefore, using a gyro error calculation, the gyro error is:

G: 236.2° pgc (Given)
E:
T: 236.2° T (Calculated)

**Gyro Error = 0.0°**