



**MERCHANT SHIPPING SECRETARIAT
GOVERNMENT OF SRI LANKA
CERTIFICATE OF COMPETENCY EXAMINATION**

GRADE : OFFICER IN CHARGE OF A NAVIGATIONAL WATCH ON SHIPS OF 500
GT OR MORE (UNLIMITED)

SUBJECT : PRINCIPLES OF NAVIGATION

DATE : 29 Apr 2024

Time : 1300 to 1600 hrs

Time allowed **THREE hours**

Total marks : 120

ANSWER ALL QUESTIONS

Pass marks : 50%

Formulae and all intermediate steps taken in reaching your answer should be clearly shown. You may draw sketches wherever required. Electronic devices capable of storing and retrieving are **not** allowed.

1). a) Define the following celestial references with suitable diagram

- i. Declination
- ii. GHA
- iii. Azimuth (12 marks)

b) Write short notes on following

- i. Solar system
- ii. Zodiac belt (08 marks)

2). a) Why does a star appear to rise, culminate and set 4 minutes earlier each day? (10 marks)

b) What is a “Circumpolar Body”? (05 marks)

c) What conditions to satisfied to be Circumpolar body. (05 marks)

3) a) Explain how to find equation of time from Nautical Almanac with suitable example. (05 marks)

b) Describe components E1 and E2 reaching nil during the year with suitable diagrams and graph. (10 marks)

c) Define the following:

- i) Sidereal Year
- ii) Anomalistic year (05 marks)

- 4) a) Discuss the reason for Northern Hemisphere seasonal changes (05 marks)
- b) Explain with suitable diagram cycle of seasons in Northern Hemisphere (10 marks)
- c) Describe Elongation of a planet with a sketch. (05 marks)
- 5) a) “The entire period of the Twilight is divided into three stages”. According to the above statement describe the three stages of the Twilight period. (08 marks)
- b) Explain which Twilight region suitable navigator take star observation. (07 marks)
- c) Describe what is Magnitude of a celestial body and how you find the magnitude of celestial bodies. (05 marks)
- 6) a) List corrections to be applied to Sextant Altitude to get True Altitude. (05 marks)
- b) Explain four Altitude corrections with suitable diagrams. (10 marks)
- c) Tabulate corrections to be applied to Moon’s sextant altitude to get True altitude. (05 marks)

Answer Sheet :

1). a)

i) . Declination of a celestial body is the arc of a celestial meridian or the angle at the center of the Earth contained between the Equinoctial and the parallel of declination through that body. Declinations are measured from 0° to 90° N or S of the Equinoctial.

ii) GHA of a celestial body is the arc of the Equinoctial or the angle at the celestial poles contained between the celestial meridian of Greenwich and the celestial meridian of the body, measured westward from Greenwich.

iii). The azimuth of a celestial body is the arc of the observer's rational horizon or the angle at his zenith contained between the observer's celestial meridian and the vertical circle through that body.

b).

(i) The Solar System is the gravitationally bound system of the Sun and the objects that orbit it, either directly or indirectly. Of the objects that orbit the Sun directly, the largest are the eight planets, with the remainder being smaller objects, the dwarf planets and small Solar System bodies.

There are eight planets in the solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The four inner solar system planets (Mercury, Venus, Earth, and Mars) fall under the category of *terrestrial planets*. Jupiter and Saturn are *gas giants* while Uranus and Neptune are the *ice giants*.

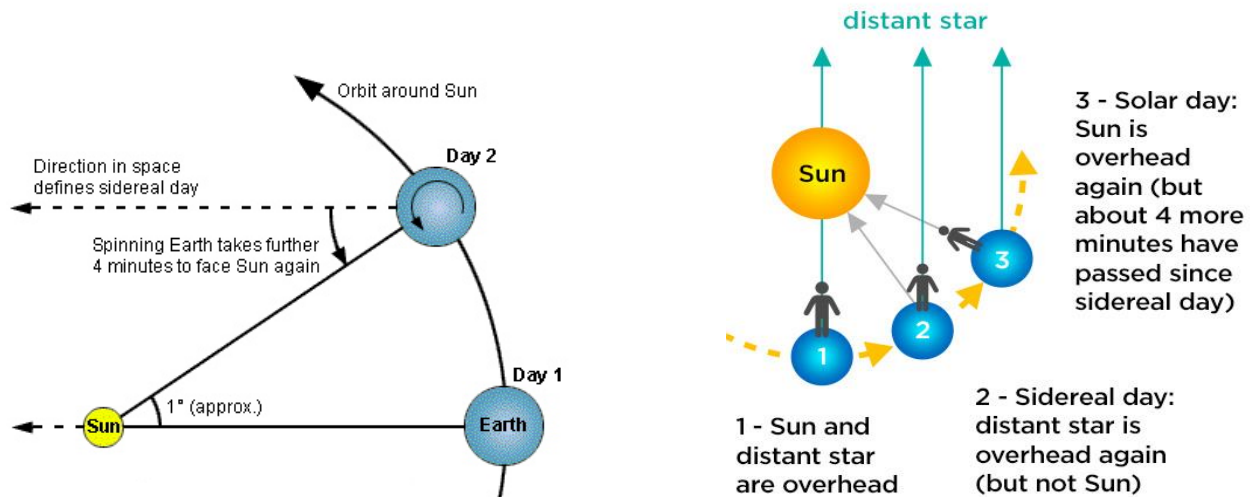
(ii) Zodiac is a belt on the celestial sphere extending 8° on each side of Ecliptic. Within which the sun, the moon and the planets are always found. The belt of the zodiac is divided into 12 equal parts of length 30° each. These parts are named after groups of star constellations within them. They are Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius and Pisces.

2). a).

The Sun makes an apparent revolution of 360° around the Earth in about $365\frac{1}{4}$ days. Approximately 1° per day.

When Earth at E1 the Sun transit with First point of aries. After when Earth completing one revolution Earth has moved to E2 at on the orbit. Thus after completion one revolution First point of aries again will culminate and one sidereal day is completed. But to complete one solar day Earth has to move further 1° .

Since we measure time by the Sun , our clocks show 24 hours from one culmination of the sun to next, measured by our clocks. But First point of aries and stars appear to culminate every 23h 56m 04s. Earlier each day than they did the previous day. Stars therefore rise, culminate and set 4 mins before sun.



One of Diagram

b). If a celestial body always remains above the horizon, it never sets or rises. Such bodies are called Circumpolar bodies.

- c). 1. Its declination should be of the same name as the observer's latitude and
 2. Latitude + declination should be equal to or greater than 90° . ($\text{lat} + \text{dec} \geq 90^\circ$)

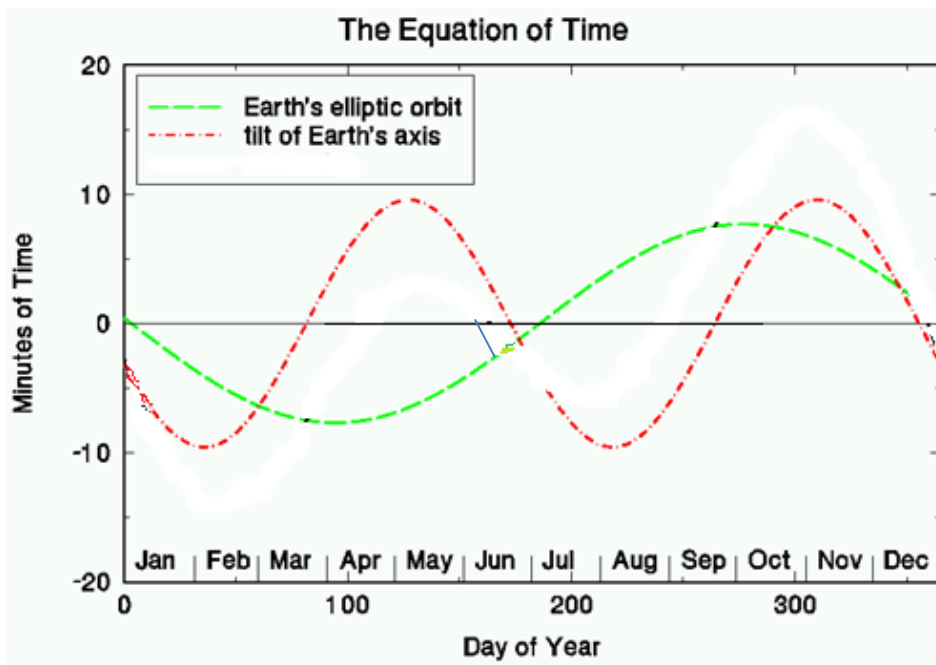
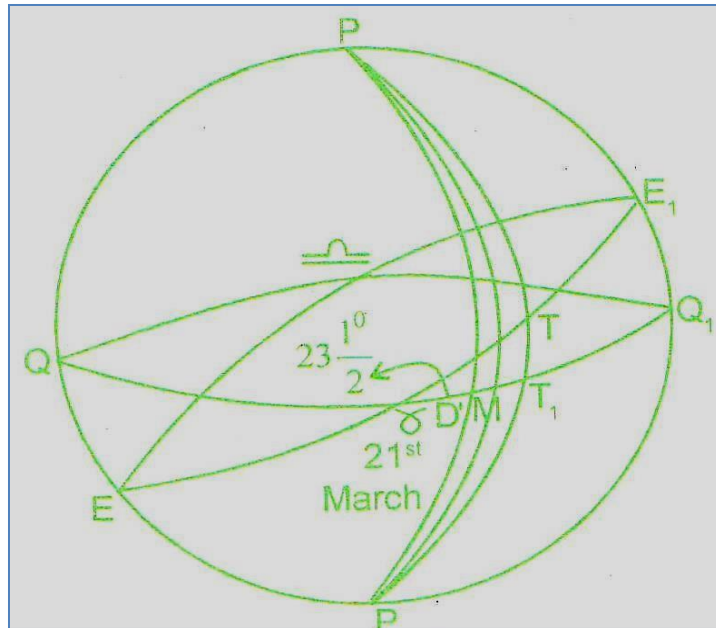
3)

a). Equation of Time values is tabulated in the daily pages of the nautical almanac, for 00 hours and 12 hours GMT on each day. The value for any intermediate time may be obtained by interpolation. The values tabulated in the almanac are the absolute values i.e. signs are omitted. Whether it is positive or negative may however be determined by inspecting the meridian passage time of the Sun in the adjacent column of the almanac. If the tabulated meridian passage time is in excess of 12 hours, say 12 04, it indicates that at 12 04 Mean time, the True Sun is on the meridian i.e. the Apparent time is 1200. Equation of Time is then obviously +ve.

Meridian passage time - 12 hours. = Equation of time (correct to the nearest minute).

- b). Component E_1 , produced due to the eccentricity of the Earth's orbit, and
Component E_2 , produced due to the obliquity of the Ecliptic.

Candidate should explain each component reaching Nil during the year with diagram and graph.



c).

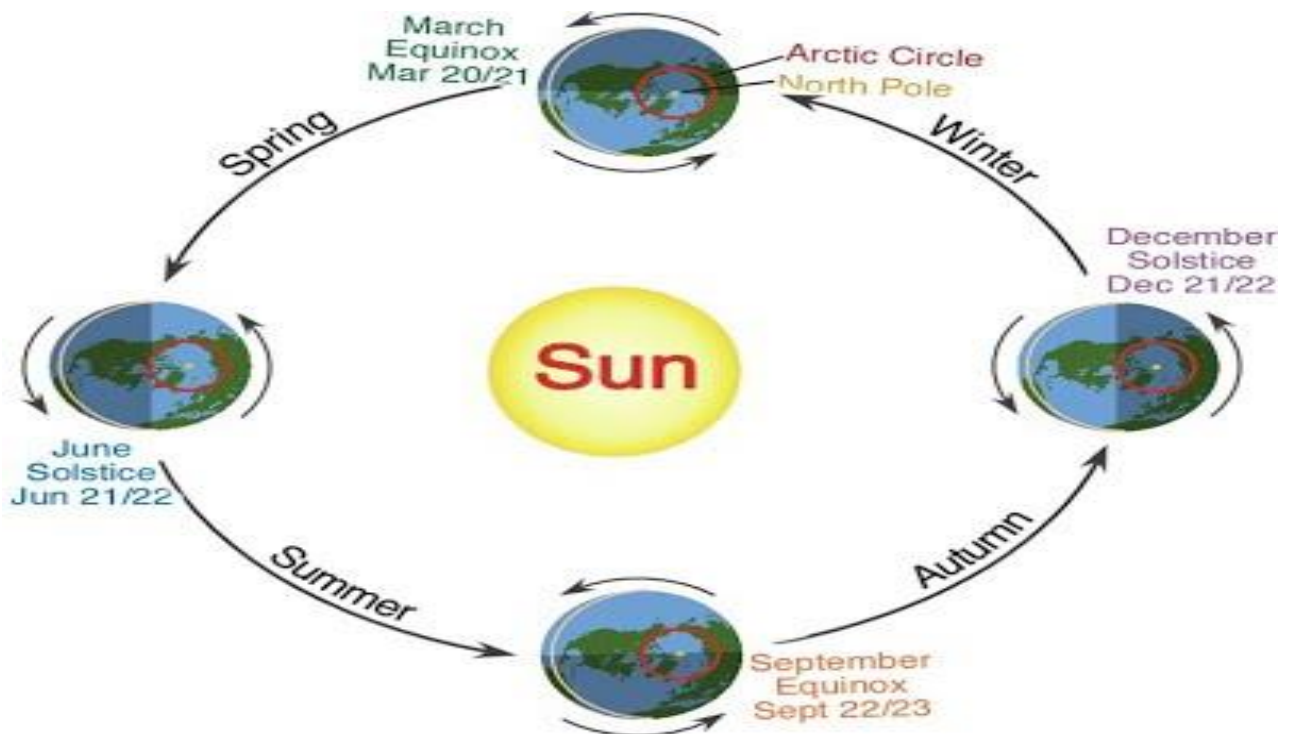
i) Sidereal Year : Is the interval in time between two successive coincidences of the True Sun's center with a fixed direction in space. In other words it is the time taken by the Earth to complete one revolution of 360° around the Sun. It is equal to 365.2564 Mean solar days.

ii) Anomalistic year : The perihelion is the point of closest approach between a planet and the Sun. The time at which a planet reaches perihelion provides a convenient measurement of the duration of the orbit. The anomalistic year is defined as the time between successive perihelion passages.

4).

a) The seasons of the earth are the result of the tilt of the Earth's axis. The Earth's axis is not perpendicular to the plane of the ecliptic. If you drew a line perpendicular to the plane of the ecliptic, the Earth's axis of rotation would be tilted, or inclined, at an angle of about $23\frac{1}{2}$ degrees with respect to the perpendicular line. It is this inclination of the Earth's axis of rotation that is the reason for the seasons. The Earth maintains the same angle of inclination throughout its orbit. This tilting is what gives us the four seasons of the year: - Spring, Summer, Autumn and Winter.

b)

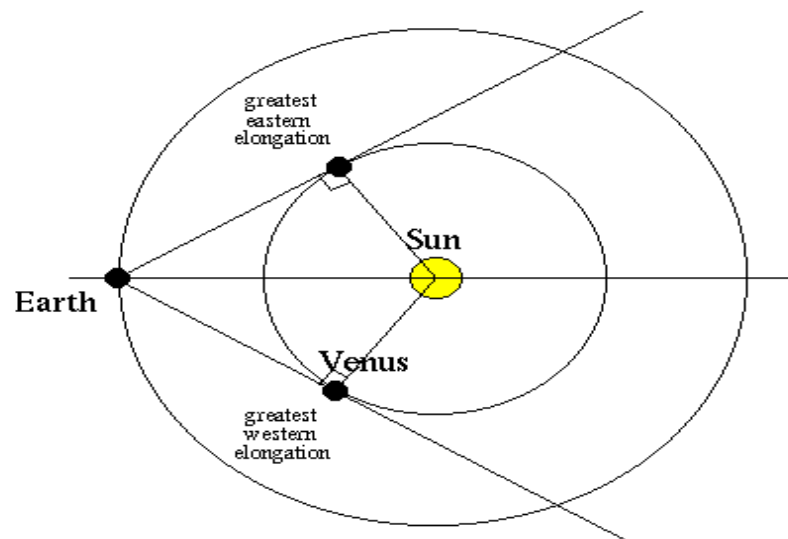


Candidate should draw a diagram and explain briefly each season.

Solstices and Equinoxes

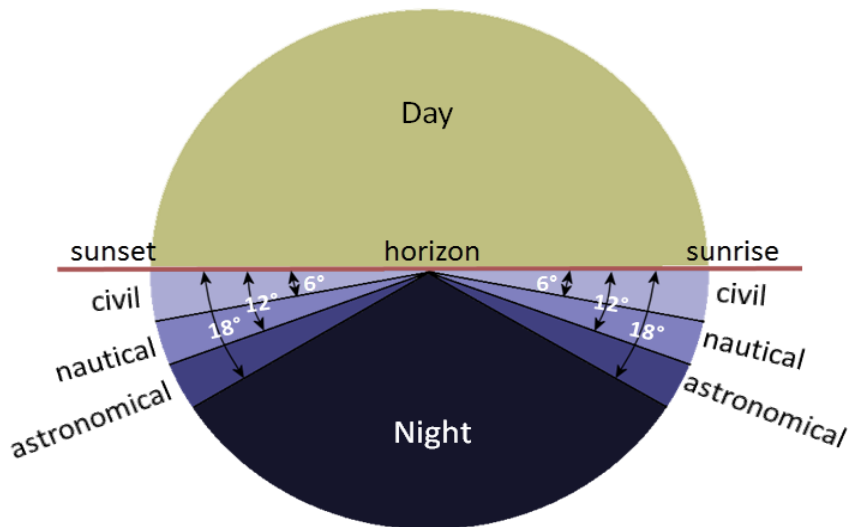
- Spring (Vernal) Equinox
 - March 20-21
 - Subsolar point at Equator
 - Circle of illumination extends to both poles
- Summer Solstice
 - June 20-21
 - Northern hemisphere tilts towards the sun
 - Southern hemisphere tilts away
 - Subsolar point=Tropic of Cancer 23.5° N
 - Above 66.5° N=24 hours of daylight (Land of the Midnight Sun)
 - 66.5° S to 90° S= 0 hours of sunlight (tilted away from the sun)
- Fall (Autumnal) Equinox
 - September 22-23
 - Subsolar point at the equator again
 - Equal hours of day and light at all locations
 - N or S hemisphere not tilted towards the sun
- Winter Solstice
 - December 21-22
 - Northern hemisphere tilted away from the sun
 - Southern Hemisphere tilted towards the sun
 - Subsolar point at 23.5° S, Tropic of Capricorn
 - Above 66.5° N, 24 hours of darkness

c)



The elongation of a planet or the moon is the angle at the centre of the Earth contained between the centre of the Sun and the centre of the planet or the Moon, measured along the plane of the ecliptic.

5). a).



Civil twilight

In the morning civil twilight commences when the Sun's centre is 6° below the rational horizon. In the evening civil twilight, continues till the Sun's centre is 6° below the rational horizon. During the period of civil twilight, the horizon is very clearly visible and the sky is fairly bright. Therefore stars are not visible for stellar observation.

Nautical twilight

In the morning nautical twilight commences when the Sun's centre is 12° below the rational horizon and continues till sun is 6° below the rational horizon. In the evening nautical twilight commences when the Sun's centre is 6° below the rational horizon and continues till it is 12° below the rational horizon.

Astronomical twilight

In the morning, Astronomical twilight commences when the Sun's centre is 18° below the rational horizon and continues till sun is 12° below the rational horizon. In the evening astronomical twilight commences when the Sun's centre is 12° below the rational horizon and continues till it is 18° below the rational horizon.

b). Nautical twilight region is the best to get Star sights. When the Sun is between 6° and 12° below the horizon, the sky is dark enough for the bright stars to be seen and the horizon is clear enough for stellar observations. Star sights are therefore best obtained during this period. When the Sun is between 12° and 18° below the horizon, most stars are visible but the horizon is too dark for celestial observations.

c). Magnitude : In astronomy, *magnitude* is a unit to measure the brightness of an object to the *unaided eye*. Brightness of stars is assigned a number starting with the brightest star starting at about minus - 1 magnitude. Dimmer stars are zero or positive numbers. The larger the number means the dimmer the star is. For example, a star -1 magnitude is brighter than a star 0 or +1 magnitude.

Magnitude of stars and planets given in Nautical Almanac, Nories tables and Sight reduction tables.

- 6).a) 1. Index Error
2. Dip/ Height of Eye
3. *Refraction*
4. *Semi-Diameter*
5. *Augmentation of the Moon's SD*
6. *Parallax in Altitude*

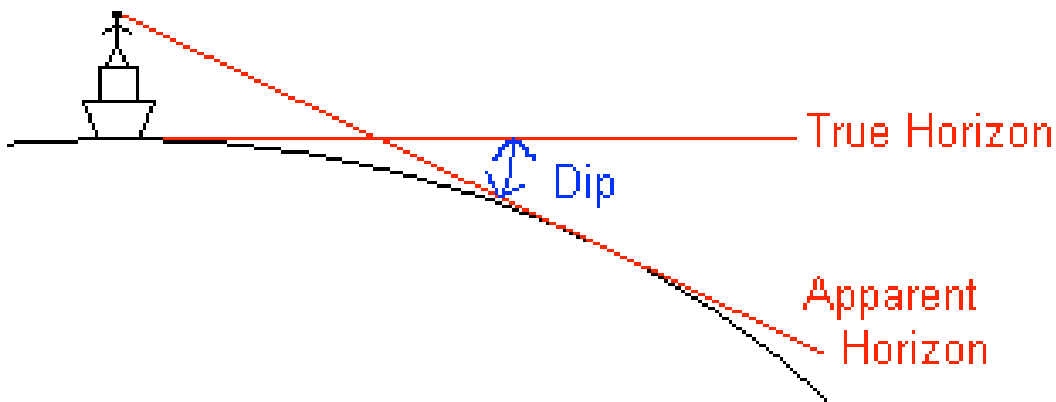
b). 1. Index Error

This error can be found using the horizon. The sextant's altitude is set to zero and then the two images of the horizon are aligned. The Index Error can then be read off. If the sextant altitude reads high, the correction is subtractive and termed "On the Arc." "Off the Arc" is the opposite. After Index Error has been applied, the Sextant Altitude it is referred to as the Observed Altitude.

2. Dip/ Height of Eye

Altitude Correction for Dip has to be made to the sextant altitude to allow for the height of the observer's eye above the horizon; this is known as Dip. Consider the diagram below: O is an observer's position on the Earth's surface and E is the position of his eye.

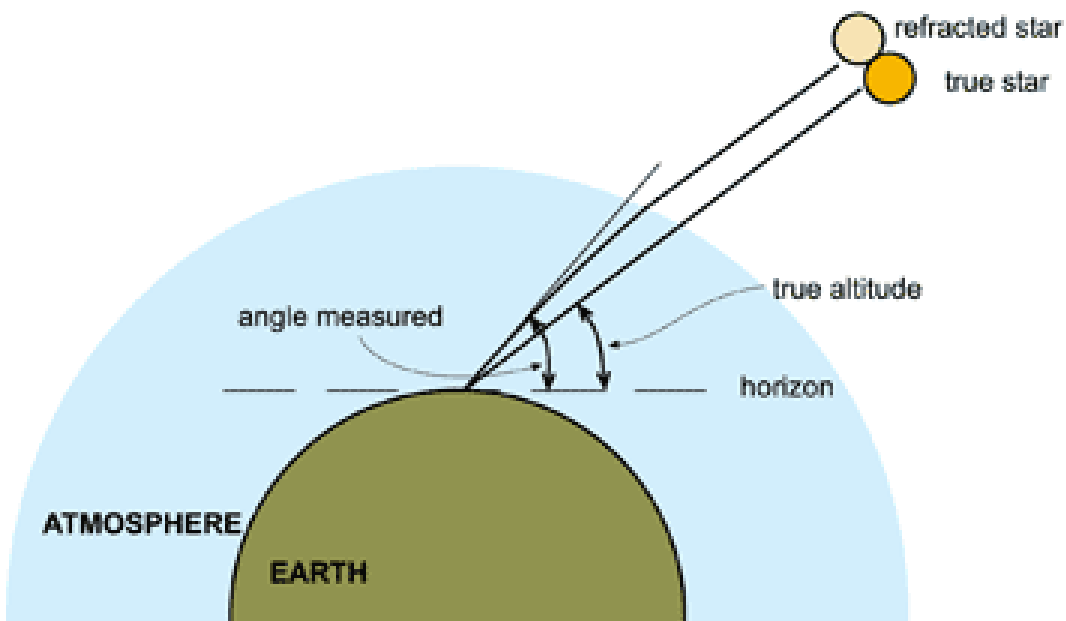
Dip is subtracted from the Observed Altitude to give Apparent Altitude.



3. Refraction

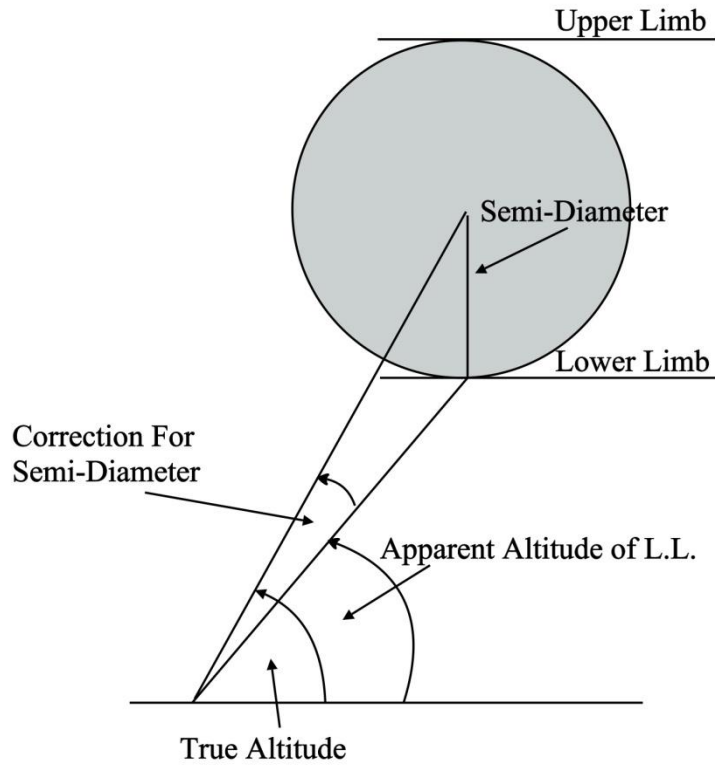
Atmospheric refraction is the deviation of light or other electromagnetic wave from a straight line as it passes through the atmosphere due to the variation in air density as a function of height. Astronomical or celestial refraction causes astronomical objects to appear higher above the horizon than they actually are.

Refraction is subtracted from the Apparent Altitude to obtain the True Altitude.



4. Semi-Diameter

When measuring the altitudes of the Sun, Moon, Venus and Mars, it is usual to use either the top (Upper Limb) or bottom (Lower Limb) of the body. This offset must then be removed before comparison with the calculated value. The angular diameter of a body depends on its distance from the Earth. Thus for the Sun the Semi-Diameter varies between 16'.3 in January, when the Sun is closest and 15'.7 in June when it is furthest away. For a lower limb observation, the SemiDiameter should be added to the True altitude.



Semi-Diameter From Lower Limb

c).

For Moon
a) IE
b) Dip
c) Refraction
d) Augmentation SD
e) Parallax in alt.
f) UL /LL correction