

---

## Positional Astronomy

Name:

Program: STP2025–FirstCourse

Date:

Worksheet: Introductory 1

---

### Academic Integrity Pledge

I affirm that the assignments I have submitted as part of the course are my own work based on my understanding of the presented content and interactions within the course. I have not received unauthorized help from any third person or text-generating software to answer the questions. Should there be evidence of plagiarism or AI-assistance in my submitted work, I forfeit my eligibility for the program completion certificate.

I affirm the pledge

I do not affirm the pledge

### Understanding the changing sky<sup>1</sup>

Pune coordinates: Latitude: 18°5 Longitude: 73°8

Alternate coordinates: Longitude: \_\_\_\_\_ Latitude: \_\_\_\_\_

## 1 Horizontal coordinate system

### 1.1 Locations on Earth: latitude and longitude coordinate system

<https://astro.unl.edu/classaction/animations/coordsmotion/longlat.html>

**Question 1.** *What is the longitude and latitude of your location? Use these coordinates and the radius of the Earth (approximately 6400 km) to determine the distances from your location to the (i) the North pole (ii) the closest point on the equator, and (iii) the south pole.*

---

<sup>1</sup>Produce for ACE IUCAA by Prakash Arumugasamy. You are free to use these questions or adapt them as per your teaching needs. For any comments or questions, please email us at [nrciucaa@gmail.com](mailto:nrciucaa@gmail.com)

**Question 2.** *The Indian Standard Time (IST) uses longitude  $82^{\circ}30'$  East as reference meridian. What is the angular separation between your longitude and the IST reference meridian? If the  $360^{\circ}$  of longitude is equated to 24 hours of time, the angular separation computed above corresponds to what time interval? What is the physical interpretation of this time difference?*

## 1.2 Cardinal directions and meridian

**Question 3.** *If local North is given a reference angle of  $0^{\circ}$  and the angular separation increases toward East, what is the angular separation between the North and West cardinal points? What is the angular separation of South-West (midway point between cardinal South and West) from the North?*

**Question 4.** *What is the angular separation of the point directly overhead from the cardinal points N, E, S, & W? The local Meridian is an imaginary line that connects the local cardinal South to the North passing through the Zenith (the point directly overhead). What is the total angle subtended by the local meridian on the sky?*

## 1.3 Altitude and Azimuth definitions

Altitude is the angular separation of any location on the sky from the closest point on the local horizon. Azimuth of a direction is the angular separation, along the horizon, of the direction from the North cardinal point.

The Altitude/Azimuth (Alt/Az) coordinate system is visualized in the following interactive animations: [https://javalab.org/en/horizontal\\_coordinate\\_system\\_en/](https://javalab.org/en/horizontal_coordinate_system_en/)  
<https://astro.unl.edu/classaction/animations/coordsmotion/altazimuth.html>

**Question 5.** *For your latitude, what is the altitude of the North celestial pole point — the point in the sky directly above the Earth’s north pole?*

**Question 6.** *What are the altitude and azimuth of a star visible 10 degrees away from the zenith and exactly in between the West and North directions?*

**Question 7.** *If an observer ‘A’ at latitude  $20^\circ$  North observes a star at an altitude of  $75^\circ$  and azimuth of  $0^\circ$ , an observer ‘B’, at latitude  $50^\circ$  North and same longitude as observer ‘A’ and observing at the same time, will see the star at what altitude and azimuth?*

## 1.4 Daily changes in the sky viewed in local coordinates

Check the following interactive animation that visualizes the daily changes in the local sky: [https://javalab.org/en/constellations\\_en/](https://javalab.org/en/constellations_en/)

**Question 8.** *You can select the ‘Run’ option to make the animation simulate the daily changes in the sky. How would you describe the motion of the stars, constellations, and the Sun in the sky during the course of a day? In which directions do they rise and where do they set?*

**Question 9.** *For your location and current time of the year, the Sun rises and sets from which direction? Exactly the east/west direction, or north/south of east/west? Include your location and current time of the year in your answer.*

**Question 10.** *The interactive animation above marks the constellations by lines and labels them. Find out the Sun is against (or nearest to) which constellation and if the constellation Orion is visible in the night sky.*

## 1.5 Local timekeeping

The following interactive animation is useful for understanding the Sun's path in the local sky. <https://www.earthspacelab.com/app/solar-time/>. Select the current month using the slider on the right panel and also set the Latitude and Longitude to your location.

**Question 11.** *In the animation above, the time shown in the bottom-left panel is the local solar time. What is the location of the Sun in the sky at 12:00 noon?*

**Question 12.** *The Indian Standard Time corresponds to local solar time on 82°5 East longitude. Accounting for only the difference in your longitude and this reference longitude, at what IST do you expect the Sun to cross your meridian? You may ignore the effect of Sun's motion with respect to the stars to get the approximate time.*

**Question 13.** *If the star Sirius crosses the IST reference meridian at 10:00 PM IST, when do you expect Sirius to cross your meridian according to the Indian Standard Time?*

## 2 Earth's orientation and motions

### 2.1 Earth's rotation about its axis

**Question 14.** *If you are standing at the Earth's pole, you will not see any of the stars rise or set but just going in circles around the zenith (circumpolar). Thus the 'circumpolar' stars are within  $90^\circ$  of the north celestial pole. For your latitude, what is the angular size of the circumpolar region? <https://astro.unl.edu/classaction/animations/coordsmotion/celhorcomp.html>*

**Question 15.** *What is the main practical inconvenience of using the rotation of the Earth with respect to the stars as the definition of a day?*

**Question 16.** *Mean Solar day of 24 hours is defined as the average time taken for the Sun to come back to its original position after one rotation of the Earth. If the Sun moves Eastward with respect to the fixed stars at the rate of about  $1^\circ$  per day, what is the time taken for the Earth to face the same fixed stars in their original locations on the sky after one rotation of the Earth?*

## 2.2 Earth's orbital motion around the Sun

**Question 17.** *Viewed from above the Earth's orbit (looking down onto the Earth's north pole), in which direction does the Earth revolve around the Sun? Viewed from the Earth, what apparent motion does the Sun assume solely due to the orbital motion of Earth?*

<https://astro.unl.edu/classaction/animations/coordsmotion/eclipticsimulator.html>

[https://javalab.org/en/celestial\\_equator\\_and\\_the\\_ecliptic\\_en/](https://javalab.org/en/celestial_equator_and_the_ecliptic_en/)

**Question 18.** *What are Solstices and Equinoxes in the Earth's orbital motion? What is the location of the Sun on the sky during equinoxes and in what direction does the Sun move as it passes the spring and autumnal equinoxes?*

## 2.3 Inclination of Earth's axis

**Question 19.** *When are the zero shadow days at the equator? When are the lengths of day and night equal at your latitude?*

[https://javalab.org/en/diurnal\\_motion\\_of\\_sun\\_en/](https://javalab.org/en/diurnal_motion_of_sun_en/)

**Question 20.** *What is the inclination angle of the Earth's axis with respect to the ecliptic plane? What is the maximum altitude the Sun reaches at your latitude during the equinoxes and the solstices?*

### 3 Equatorial coordinate system

An interactive equatorial coordinate system simulation can be accessed here:

<https://astro.unl.edu/classaction/animations/coordsmotion/radecdemo.html>

Also [https://javalab.org/en/equatorial\\_coordinate\\_system\\_en/](https://javalab.org/en/equatorial_coordinate_system_en/)

#### 3.1 Sun's path on the sky, Equinox and Solstice

**Question 21.** *What are the right ascension and declination of the Sun at Summer solstice and autumnal equinox, if the origin of the equatorial coordinate system is chosen to be the Sun's location at spring equinox of the current year?*

**Question 22.** *What declinations are always visible from your location and what declinations are never visible from your location?*

#### 3.2 Right ascension and Declination

**Question 23.** *Is a star at Right Ascension  $\alpha = 4^h 30^m$  and Declination  $\delta = 23^\circ 8'$  visible from  $20^\circ$  North latitude at midnight in October?*

**Question 24.** *A star at right ascension  $21^h$  will transit your meridian (reach the highest point in the sky) at approximately what time on the day of the summer solstice?*

### **3.3 Solar and Sidereal time**

**Question 25.** *What is the main practical inconvenience of using the rotation of the Earth with respect to the stars as the definition of a day?*

**Question 26.** *How many solar days and sidereal days are there in a tropical year? The tropical year is defined as the time the Sun takes to appear at its original position with respect to the fixed stars after one orbit of Earth.*

### **3.4 Precession and epoch**

**Question 27.** *If the precession of the Earth's axis has a period of 25,772 years, what is the approximate error in positions one makes by ignoring the effect of precession on the equatorial coordinate system between the reference epoch year 2000 and the current year 2025?*

## 4 Spherical trigonometry

### 4.1 Spherical triangles

**Question 28.** *Which of the following are great circles?*

- Your local meridian*
- Equator*
- lines of longitude*
- lines of latitude*
- ecliptic*
- line of constant azimuth*
- lines of constant declination*

**Question 29.** *Intersection of which of the following lines form a spherical triangle?*

- Equator,  $0^\circ$  longitude, and  $90^\circ$  E longitude*
- Ecliptic, Celestial equator, and line of  $23.5^\circ$  right ascension*
- line of  $0^\circ$  right ascension, line of  $23.5^\circ$  right ascension, and line of  $45^\circ$  declination*
- Local meridian, celestial equator, and ecliptic*

**Question 30.**

1. *Imagine that a technologically advanced, but highly mischievous, space aliens have reduced the tilt of the Earth's rotation axis from  $23.5^\circ$  to  $0^\circ$ , while leaving the Earth's orbit unchanged. Sketch the analemma in this case.*
2. *Now imagine that the aliens have restored the axial tilt to its previous value of  $23.5^\circ$  but have changed the Earth's orbit to a perfect circle, with the Earth's orbital speed being constant over the course of a year. Sketch the analemma in this case.*
3. *The martian analemma is shown in the figure below. What is the tilt of the rotation axis of Mars?*

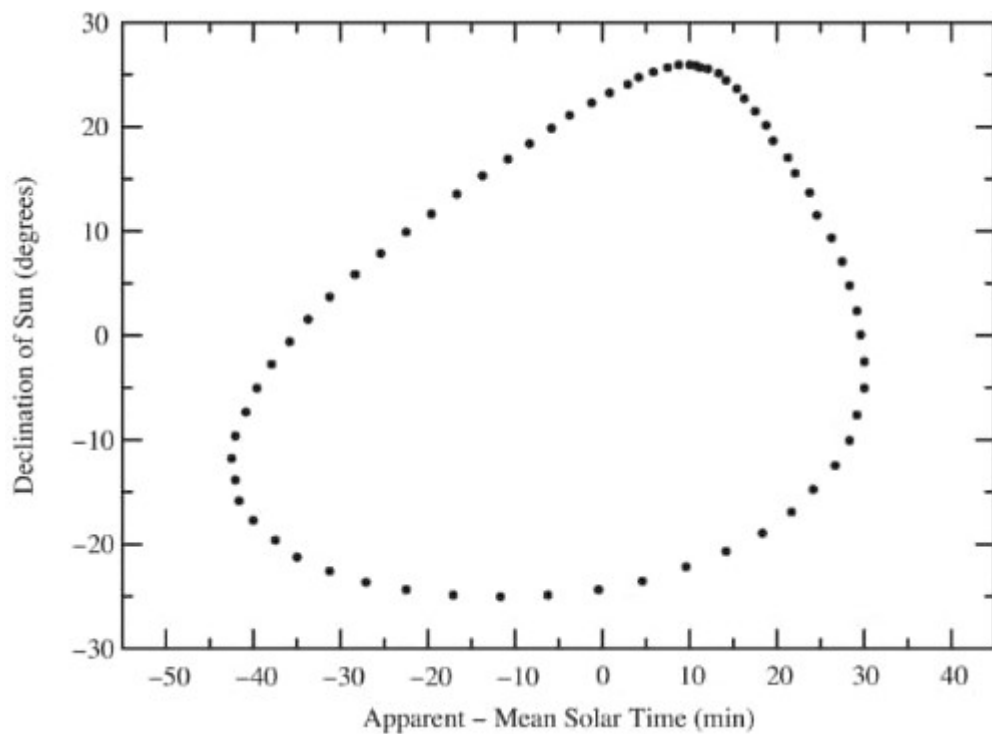


Figure 1: The solar analemma viewed from the planet Mars.