Fantastic!!

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PHYS 454

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HW#1

1: 5+5 = 10/10
2: 10/10
3: 5+5 = 10/10

30/30

Question 1 – Sun Tower

a) The location, which is Huntsville, Alabama, has longitude -86.602^{O} and latitude 34.74^{O} [1]. On February 1st, 2024, the Sun is at its highest elevation at 18:00 (6pm CST or 7pm EST), as shown in **Figure 1**. This data was queried from JPL Horizons [2].

That’ 6pm UTC - 12 in CST

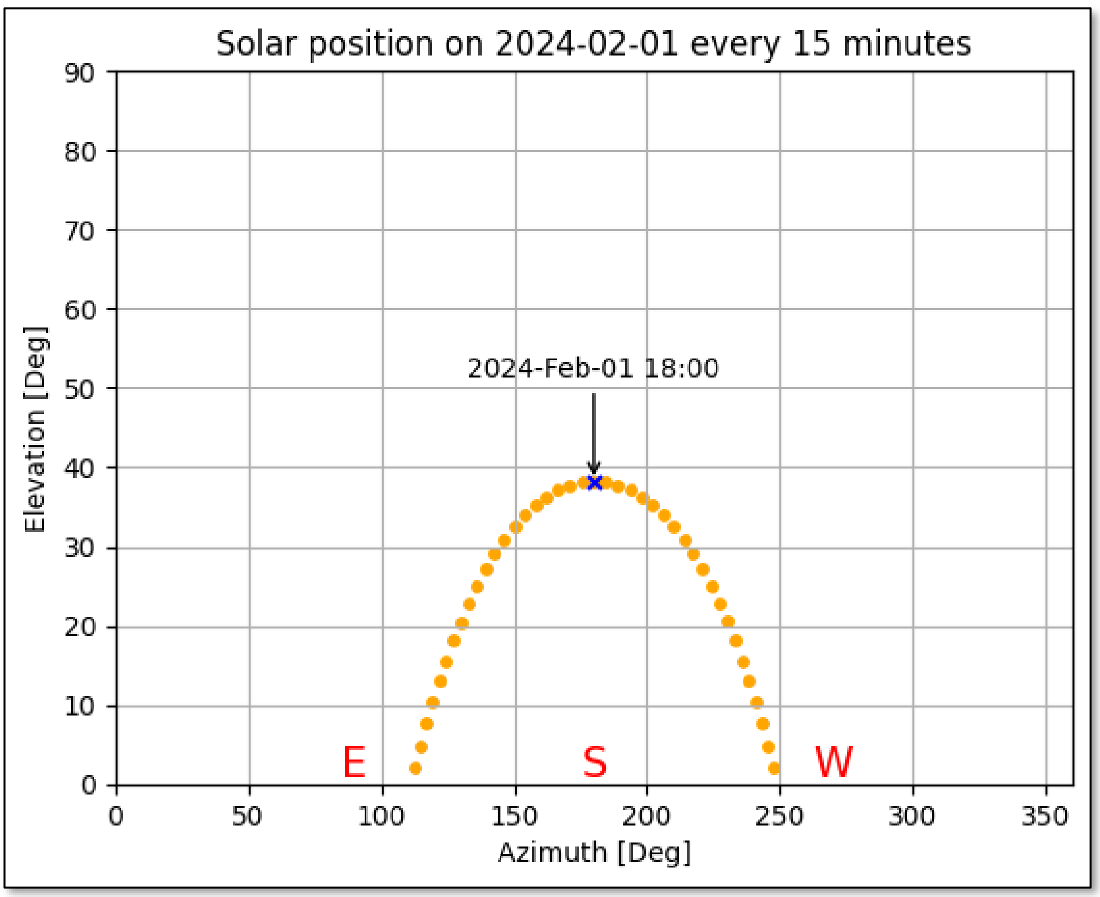
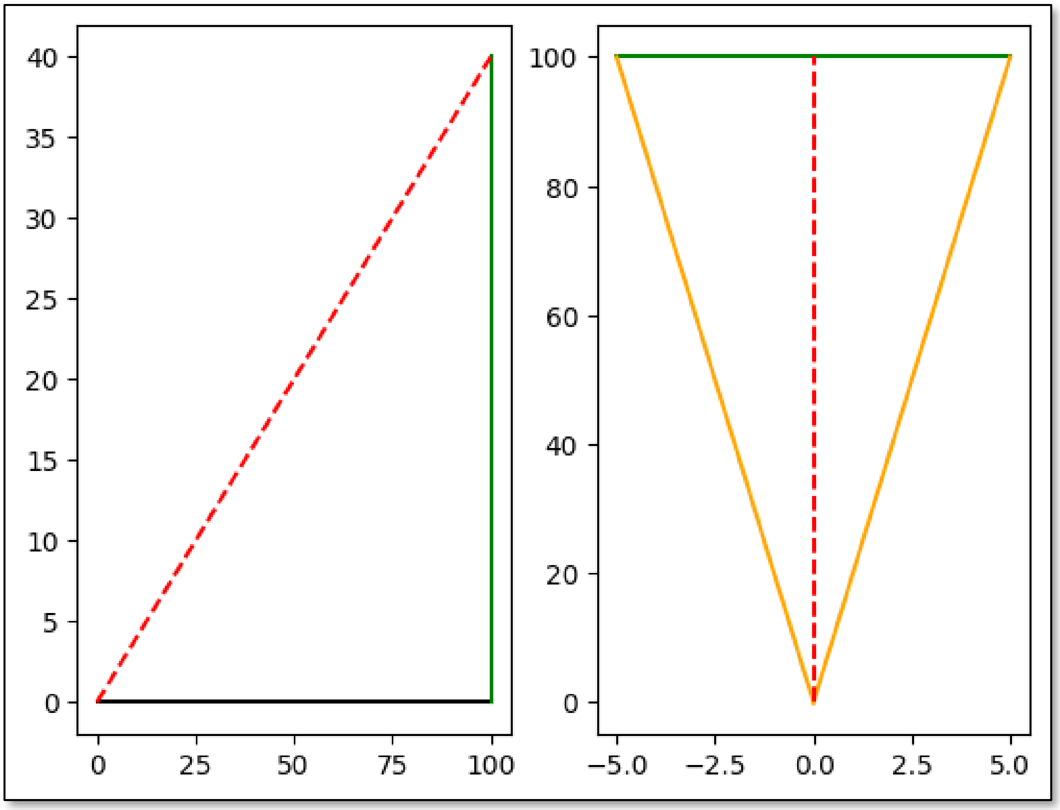


Figure 1: Sun Ephemeris (yellow dots) with highest elevation of Sun (blue cross)

Now the tower that is 100m away from us, being 40m tall and 10m wide, needs to be considered. Given these 3 dimensions, we can create trigonometric relationships and obtain the elevation and azimuthal coordinates of the tower. The side and top view are shown below in **Figure 2**.



Nice figures!

Figure 2: Top View (left) and Side View (right) of the tower (green) from the observer point of view defined at the origin

The equations needed are:

$$\text{Elevation Angle} = tan^{-1}\left(\frac{\text{height}}{distance}\right) \tag{1}$$

$$\text{Azimuthal Angle} = tan^{-1}\left(\frac{width/2}{distance}\right) \tag{2}$$

Equation 2 is needed for the left and right side of the tower with respect to the observer's straight-line view of the tower, hence only half of the tower's width being used. The elevation angle of the tower is calculated to be 21.8^{O} and the azimuthal half angle as 2.86^{O}. The plot of the tower with respect to the sun ephemeris is shown in **Figure 3**.

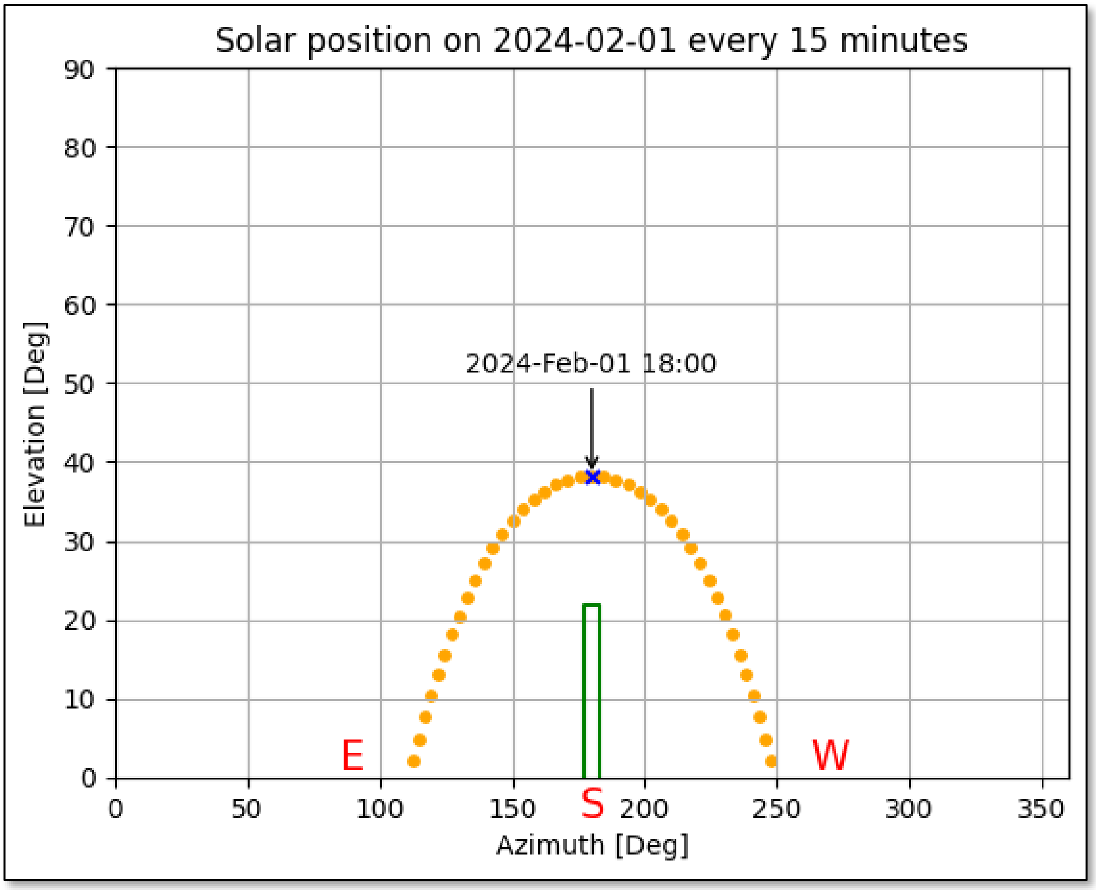


Figure 3: Sun Ephemeris and Tower (green)

b) To find the tower height needed to block the sun from the observer's perspective, we can work backwards using **Equation 1** by using the max sun elevation for elevation angle and solving for tower height. The max sun elevation, found using the np.max() function on the sun ephemeris elevation angles, is found to be 38.17°. The following calculation is done to find the tower height:

$$tower\ height = distance \times tan(\text{max sun elevation}) = 100 \times \tan(38.17^{\circ})$$
$$\Rightarrow \text{tower height} = \boxed{78.6 \text{ meters}} \text{ tall to block sun}$$

Yes

Question 2 – 1610 was an exciting Year

On February 15th, 1610, Galileo observed Jupiter and some of its moons in Padua, Italy. His drawing from his text *Siderius Nuncius* [3] is shown in **Figure 4**.

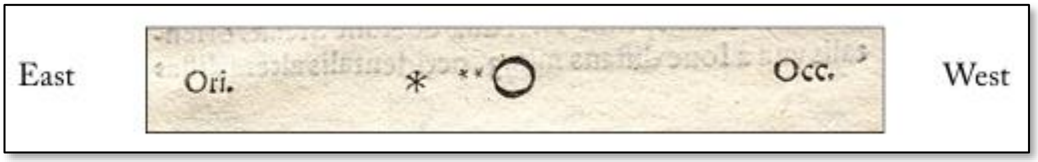


Figure 4: Galileo's drawing of Jupiter and its moons from Siderius Nuncius

This occurred, according to online sources [4], on the *First Hour*, or at around 17:00:000 UTC (5:00pm). From JPL Horizons [2], the azimuthal and elevational angles were obtained based on the date and the latitude/longitude of Padua (45.4064° N, 11.8768° E). The following graph was obtained, shown in **Figure 5**.

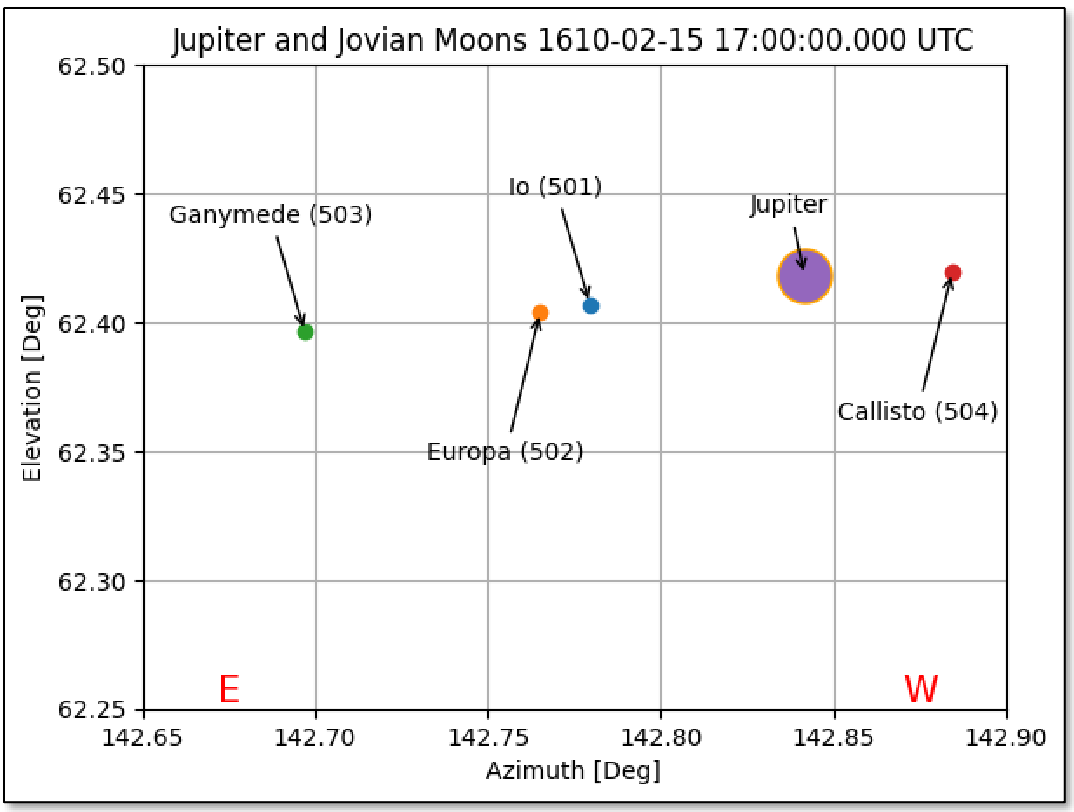


Figure 5: Positions of Jupiter and its moons: Io, Europa, Ganymede, and Callisto; during the mentioned date and time

Upon comparing **Figure 4** and **Figure 5**, many similarities can be pointed out – a "star" far East of Jupiter and two "stars" close to each other, closer to Jupiter. However, Callisto, which is West of Jupiter, is clearly visible. Perhaps Galileo's azimuthal view did not extend far enough, or the elevation range he used would exclude Callisto from his view due to its misalignment with Jupiter and the three other moons.

My guess is that Callisto was too close to Jupiter and it just looked like it was part of Jupiter.

Question 3 – Analemma plots

a) To create an Analemma plot of the Sun for 2024, we need to query the sun's position everyday from January 1st to December 31st in 2024. For an observer in Prospect Park, NYC, for 2:00pm UTC (9:00am EST), the Analemma plot for 2024 is shown in **Figure 6**.

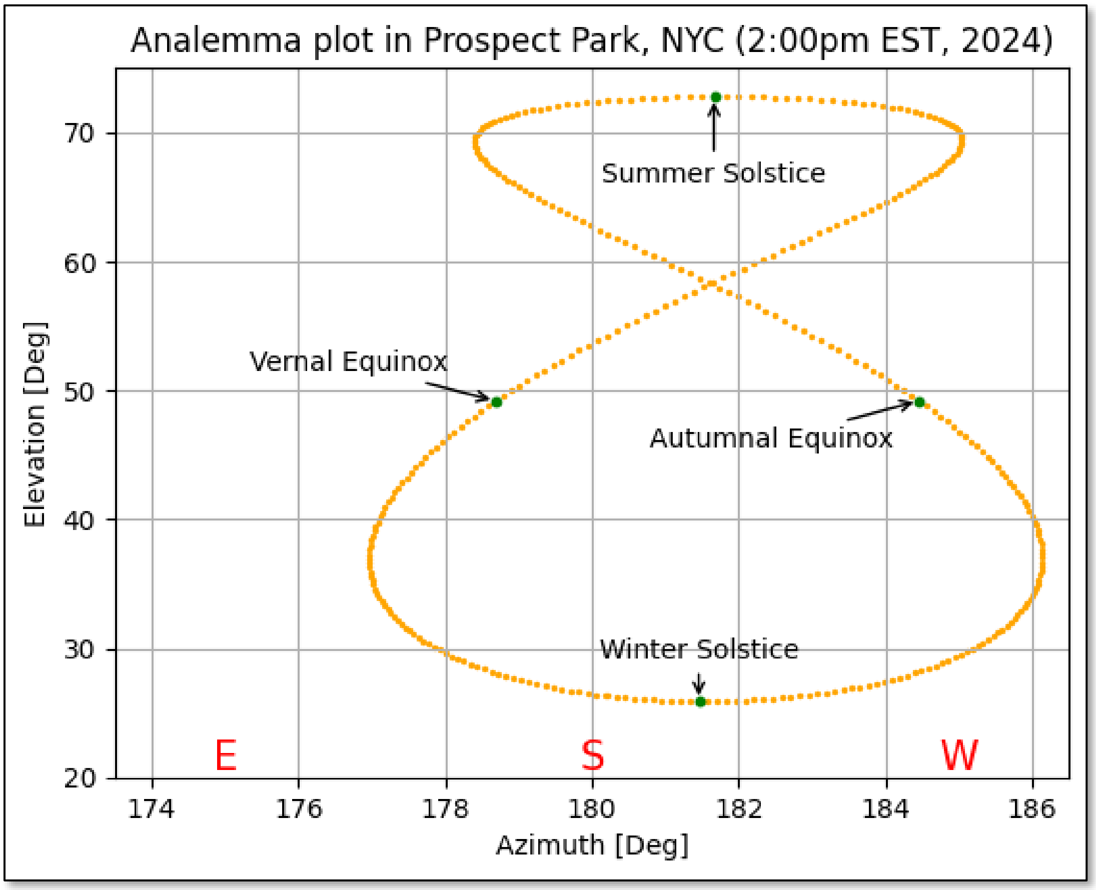


Figure 6: 2024 Analemma from Prospect Park, NYC, with special times of the year

The Summer and Winter Solstices and the Autumnal and Vernal Equinoxes are also labeled in the plot.

b) For a location in the Southern Hemisphere, the location Cape Town, South Africa was chosen, for 6:00am UTC. The Analemma is shown in **Figure 7**.

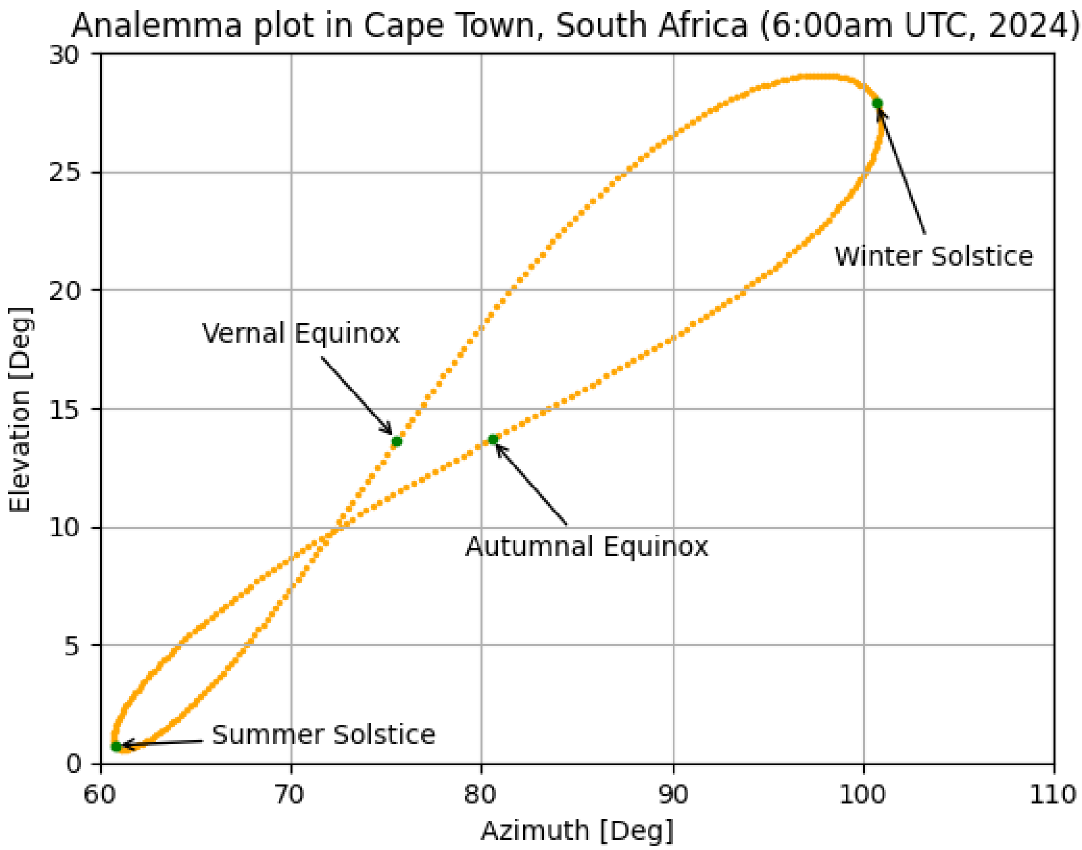


Figure 7: 2024 Analemma from Cape Town, South Africa, with special times of the year

References

[1] https://www.latlong.net/place/huntsville-al-usa-2303.html

[2] Horizons System (nasa.gov)

[3] SideriusNuncius.pdf (cuny.edu)

[4] Galileo's First Jupiter Observations - 4 (etwright.org)

[5] Source Code - https://colab.research.google.com/drive/1HkMurCP50Yf4r7tmrNl3upeEJra3OjWd?usp=sharing