

# TUTORIAL 1

## Class Assignment

### 1 Basics with Stellarium

#### Installation

You will need a laptop/PC which supports Windows 7 and above, MacOS or a Linux/ Unix OS. Go to the following link: <http://www.stellarium.org/> On the top-most panel, you will see the Stellarium packages for different Operating Systems. Choose the appropriate option for your machine and



download the package. Double click the file you have downloaded and follow the instructions given on screen for the installation. You can also download the User Guide to using Stellarium, which is also available on the top panel of the website.

Once you have successfully installed Stellarium into your computers, start up the program. You should see the following on your screen.



Take some time to explore the various keys and options in the menu on the bottom panel. Move your cursor to the far left of the screen where a panel will appear. Open the Location Window and click on the map to select a location near where you live; it does not need to be exact. Click on "Use Current Location as Default." You can also change your geographical location to different places on Earth. You can change the time, background, turn on the night mode etc.. Your Teaching Assistants will help you understand some handy tips and tricks. Go to the Date and Time menu. Change the time and watch as the constellations move through your line of sight. Now change the year, and do the same. Change the month and day, and watch as the days turn into nights. Generate images of the constellations in the night sky.

### **Tasks with Stellarium**

Choose any location on the Earth and set it up in Stellarium. Try to answer the following questions:

**Q1.** What planets can you see at midnight?

**Q2.** What planets are 'hidden' below the horizon?

**Q3.** How do the stars appear to you? Are all of them similar? Comment.

**Q4.** What happens if you speed up/slow down the time?

**Q5.** What constellations are circumpolar from your location?

**Q6.** Go back 100 years into the past. Do you see any change in the night sky at the same location?

**Q7.** Can you identify all the zodiac constellations? Do they follow a pattern with respect to the sun?

**Q8.** Can you identify the pole star Polaris? If you change your location to Auckland, can you see a southern pole star? You could set up coordinate grids to help identify the poles.

## **2 Windows on the past**

Born around 275 BC in Cyrene, a former Greek town in what's eastern Libya today, Eratosthenes moved from Athens to Egypt at the age of 30 to become the head of the Great Library of Alexandria. He was an exceptional thinker in many areas of science, history and philosophy, and geography in particular. He argued that the Earth must be spherical. After all, the Sun and the Moon were round; why not the Earth? He learned of a peculiar observation made in Syene, currently known as Aswan, due South of Alexandria along the river Nile. On June 21 at noon, the Sun was straight overhead in Syene and, consequently, the bottom of a deep well was fully illuminated by the Sun while a vertical stick did not cast any shadow. This was never seen in Alexandria. On that same day, the

Great obelisk in Alexandria would still cast a short shadow at noon (see Figure 1a). Eratosthenes realised that this must be caused by the curvature of the surface of the Earth and that this offered the possibility to measure its circumference, assuming that the Sun is at a great distance with its rays arriving in parallel at Earth.

He recognised that the top of the obelisk, the tip of its shadow together with the base of the obelisk

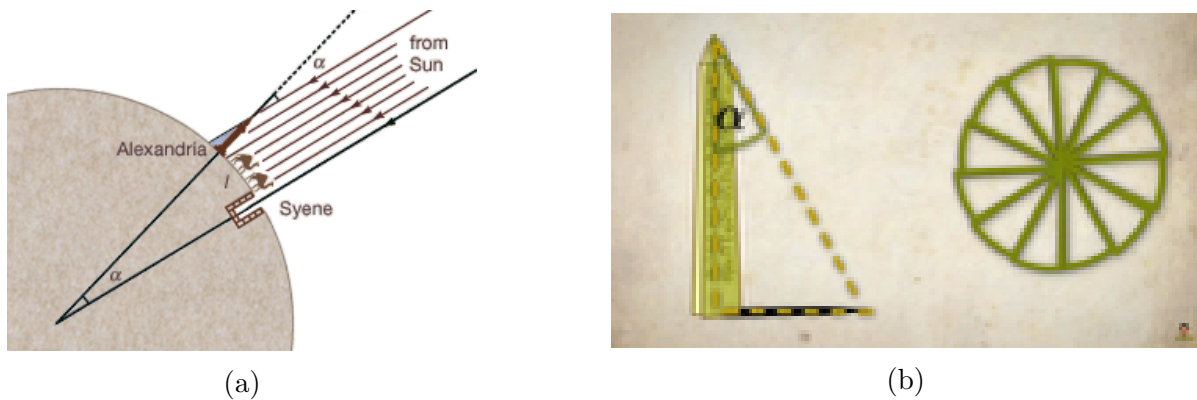


Figure 1

form a triangle with an angle  $\alpha$  at the top (see Figure 1b). Using his geometric insights, Eratosthenes realised that this angle fits 50 times in a full circle of 360 degrees and, crucially, that this same angle  $\alpha$  is also the angle between Alexandria and Syene as measured from the centre of a spherical Earth. To determine the circumference of the Earth, all he needed to do was to measure the distance between Alexandria and Syene and multiply this by  $(360/\alpha) = 50$ . Travel reports of caravans along the Nile mentioned that it takes 23 days to cover the distance between Syene and Alexandria while a caravan can walk some 220 stadia per day. What would Eratosthenes calculate as the circumference of the Earth in stadia?

Fast forward to 2017 AD: The length of 1 stadium is 158 metres. What was Eratosthenes's calculation in kilometres? (The modern, accurate measurement is 40,075 km)

### 3 Kepler's Laws

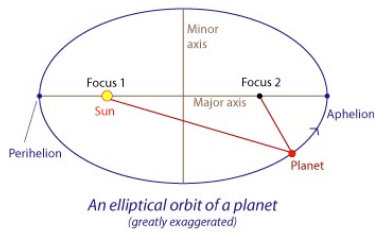
The Danish astronomer Tycho Brahe is well known for his observations of stellar and planetary positions. These observations were taken without the help of telescopes but achieved unprecedented accuracy by using large and accurate sextants. Based on these observations, Johannes Kepler formulated his empirical laws of planetary motion around the Sun. Kepler's three laws of planetary motion are described as:

#### Kepler's first law

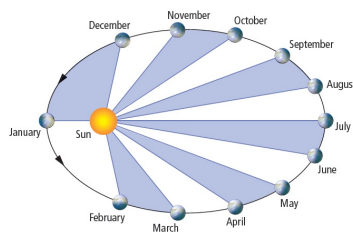
Kepler's first law, states that the orbit of a planet around the Sun is an ellipse. In such an orbit, the Sun is placed at one of the two foci of the ellipse. (see Figure 2a)

#### Kepler's second law

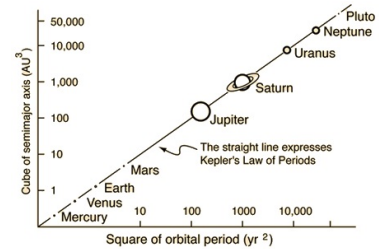
According to Kepler's second law, a planet moving in an elliptical orbit travels faster when closer to the Sun and slower when farther from the Sun. In other words, the planet spans equal areas in equal time. (see Figure 2b)



(a) First law



(b) Second law



(c) Third law

Figure 2: Kepler's laws of planetary motion

### Kepler's third law

Kepler's third law relates the orbital period of a planet ( $p$ ) to the semi-major axis of its elliptical orbit ( $a$ ). According to this law, the expression  $p^2/a^3$  has the same value for all planets in the solar system. (see Figure 2c)

To obtain a visual understanding of Kepler's law, use the Planetary Orbit simulator that can be found at:

<http://astro.unl.edu/naap/pos/animations/kepler.html>

This simulator models the motion of a hypothetical planet around the Sun, in accordance with Kepler's law. Follow the instructions given below to use the simulator:

1. Open the given web address in a web browser to launch the simulator
2. Kepler's 1st Law tab is open by default.
3. Enable all 5 check boxes. The white dot is the simulated planet. You can click on the planet and drag it around.
4. Change the size of the orbit with the semi-major axis ( $a$ ) slider. Note that the background grid indicates change in scale.
5. Change the eccentricity ( $e$ ) and note how it affects the shape of the orbit.
6. Start animation to see the motion of the planet. You may need to increase the animation rate for very large orbits or decrease it for small ones.
7. The planetary pre-sets set the planet's parameters to those of our solar system's planets. Explore these options.

Answer the questions given below.

**Q1.** For what value of  $e$  is the secondary focus (which is empty) located at the Sun? What is the shape of this orbit?

**Q2.** Create an orbit with  $a = 10$  AU and  $e = 0.4$ . Drag the planet first to the far left of the ellipse and then to the far right. What are the values of  $r_1$  and  $r_2$  at these locations? Can you find points along the orbit where  $r_1$  and  $r_2$  are equal?

**Q3.** Create an orbit with  $a = 17$  AU and  $e = 0.6$ . Drag the planet first to the far left of the ellipse and then to the far right. What are the values of  $r_1$  and  $r_2$  at these locations? Can you find points along the orbit where  $r_1$  and  $r_2$  are equal?

**Q4.** For both the cases above, what is the value of the sum of  $r_1$  and  $r_2$ ? How does it relate to the ellipse properties? Is it true for all ellipses?

**8.** Open Kepler's 2nd Law tab. Use the 'clear optional features' button to remove 1st Law features.

**9.** Press the 'start sweeping' button. Adjust the semi-major axis and animation rate so that the planet moves at a reasonable speed. Adjust the size of the sweep using the 'adjust size' slider.

**10.** Click and drag the sweep segment around. Note how the shape of the sweep segment changes, but its area does not.

**11.** Add more sweeps. Erase all sweeps with the 'erase sweeps' button.

**12.** The 'sweep continuously' check box will cause sweeps to be created continuously when sweeping. Test this option.

**Q5.** Erase all sweeps and create an ellipse with  $a = 1$  AU and  $e = 0$ . Set the fractional sweep size to one-twelfth of the period. Drag the sweep segment around. Does the sweep size or shape change?

**Q6.** Leave the semi-major axis at  $a = 1$  AU and change  $e$  to 0.5. Drag the sweep segment around and note that its size and shape change. Where is the sweep segment the 'skinniest'? Where is it the 'fattest'? Where is the planet when it is sweeping out each of these segments? (What names do astronomers use for these positions?)

**Q7.** Which value of  $e$  in the simulator results in the greatest variation of sweep segment shape?

**13.** Open the Kepler's 3rd Law tab. Use the 'clear optional features' button to remove the 2nd Law features.

**Q8.** For  $a = 5$  AU, vary  $e$  of the orbit. How does this affect the orbital period  $p$  of the planet?

**Q9.** For a fixed value of  $e$ , vary the value of  $a$  of the orbit. How does this affect  $p$  of the planet?