UNDERSTANDING TIME THROUGH STELLARIUM

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Does the Sun rise from and set at the same position every day? What does its rising and setting position have to do with the length of our days and nights? If we were to pick one of the stars we see in the night sky, and look at it every day, for a year, would it look like it never moved? How do we introduce young students to such mysteries of space and time, inside the four walls of our classroom? This article explores the use of Stellarium, a free open source software, as a teaching aid that can engage teachers and students alike, helping them visualise some astronomical phenomena, and understand concepts related to them, in a less abstract and more engaging way.

A great deal of our concept of time has come from observing the motion of heavenly bodies. The systematic way in which the Sun, the Moon, planets and stars travel across the sky, forms the basis on which days, nights, months and years are defined. The time of the day comes from the position of the Sun in the sky. The month is based on the revolution of the Moon around Earth. The year and seasons are linked to the apparent annual motion of the Sun, as seen from Earth.

In this age of digital clocks, the sky may have turned obsolete as a means to know time. But, there is still a great deal of merit in learning concepts fundamental to celestial time keeping. How well do we know answers to seemingly simple questions like where exactly does the Sun rise; is the duration of the day the same as the duration of the night; does the position of the Sun in the sky change with geographic location? Finding out answers to such questions through real world observations consume a lot of time, and are not practical at all times. Planetarium softwares can be a great substitute to real world observations.

There are several softwares that help one visualize the apparent movement of objects in the sky. STELLARIUM is one such open-source software obtainable free of cost. STELLARIUM can be downloaded from www.stellarium.org

STELLARIUM displays objects in the sky for any given date and time from a location of our choice on Earth. This software has many useful features. One can move forwards and backwards in time, zoom-away or zoom-into an object, remove Earth's atmosphere, change our location of observation, switch on the labels and boundaries for constellations, include deep-sky objects like galaxies, star clusters and many more. These features are easy to locate on the software, and are also well explained in the user's guide that comes along with the software.

This article describes a few exercises which can engage students in learning about the patterns and periods of the sky.

The rising & setting position of the Sun

We all know that the Sun seems to rise in the East and set in the West, when seen from Earth. But is this always true? Does the Sun always rise exactly due East and does it set exactly due West?

It is easy to investigate such questions with STELLARIUM. Here is a sequence of steps that may help with answers.

1. In STELLARIUM, change your viewing orientation so that you are facing EAST.
2. Set date to March 1st and time to 7:30 am (the year does not matter). You will see that the Sun has risen NOT exactly in the East, but a bit South of East (as shown in the image below)

3. Keeping the time fixed (7:30 AM), keep incrementing the date from March 1st in steps of one day. Notice how the rising position of the Sun changes.
4. You will notice that the position of the Sun drifts in the following manner
    - March 21 (± 1 day) the Sun rises exactly due east
    - From March – June, the rising Sun keeps drifting towards North of East.
    - June 21 (± 1 day), the Sun reaches maximum elongation North of East.
    - From June – September, the rising Sun starts drifting towards South.
    - September 22 (± 1 day), the Sun again rises exactly due East

- From September – December, Sun drifts towards South of East
- December 22 (± 1 day), the Sun reaches its maximum elongation South of East, and the cycle repeats.

Some facts to learn from the above exercise:

1. The Sun does not always rise exactly from the East
2. Neither does it always set exactly at the West.
3. The Sun rises exactly due east only twice a year. These two days are called vernal equinox or *Vasantha Sampath* (March 21st ± 1 day) and Autumnal Equinox or *Sharat Sampath* (September 22nd ± 1 day). “Equinox” loosely translates into “equal day and night”.
4. In the calendar system that came about in India centuries ago, the year is divided into two halves. The 6 month duration from December – June, when the rising (and setting) position of the Sun moves from South to North, is called *Uttarayana* (it means northward journey, *ayana*: journey, *uttara*: north). The other six months of duration from June – December,

The rising & setting of stars

Like the Sun, stars also seem to rise in the East and set in the West. This is because of the Earth’s spin oriented from West to East. In STELLARIUM, by increasing the time speed from the bottom control panel one can observe the apparent movement of stars in the sky, fast-forwarded in time.

when the rising (and setting) position of the Sun drifts from North to South, is called *Dakshinayana* (the journey southward).

5. Do these observations hold true if we are located somewhere in the southern hemisphere? This can be investigated by choosing a southern hemisphere location from the "Location Window" (e.g. Kuala Lumpur, Malaysia)

The duration of day & night

The rising and setting time of the Sun governs the duration of day and night. Curiously, day and night are not always of the same duration. Depending on the month of the year, a day could be longer or shorter than the night. The difference also depends on our geographic location. These concepts can be explored through STELLARIUM. For clarity, it is good to do this exercise for three different geographic locations.

From a location close to the equator

1. Choose an observing location close to the equator of Earth (e.g. Chennai)
2. Starting from the month of January, proceed in steps of one month.
3. For each month, note down the time of the day when the Sun rises from the Eastern horizon. Try to make a simple table of your recordings. Is there any trend to the rising time of the Sun over a one year time period?
4. Once you complete the above process, change your orientation towards the West
5. For January through December, note down the time when the Sun goes below the Western horizon. Again, tabulate your recordings.

Is there any trend to when the Sun sets?

From the two tables, calculate the duration of daylight / night across the year. Is there any trend in the duration of daylight compared to the duration of night for the uttarayana and dakshinayana halves of a year?

From a location away from the equator

1. Choose an observing location away from the equator (e.g. Srinagar)
2. Repeat the above procedure

From the table of values, calculate the duration of day / night. Is there any trend in the duration of daylight compared to the duration of night for the uttarayana and dakshinayana halves of a year? How does this compare with the location closer to the equator?

From the north pole

1. Choose your observing location as North Pole (latitude 90 deg North of the equator)
2. Repeat the above procedure.

What is peculiar about the day and night cycle at the North Pole? Does this explain why the North Pole is not habitable?

The rising & setting of stars

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From the soutern hemisphere

1. Choose a location close to and below the equator in the southern hemisphere (e.g. some place in Sri Lanka) and repeat the above steps.
2. Choose a location away from the equator in the southern hemisphere (e.g. Kuala Lumpur, Malaysia) and repeat the above steps.
3. Choose the South Pole and repeat the above steps.

Is there any difference in the duration of days and nights with a change in months, for those living in the southern hemisphere? Are the uttarayana and dakshniyana halves of a calendar year the same as what is seen from the Northern hemisphere?

The rising & setting of stars

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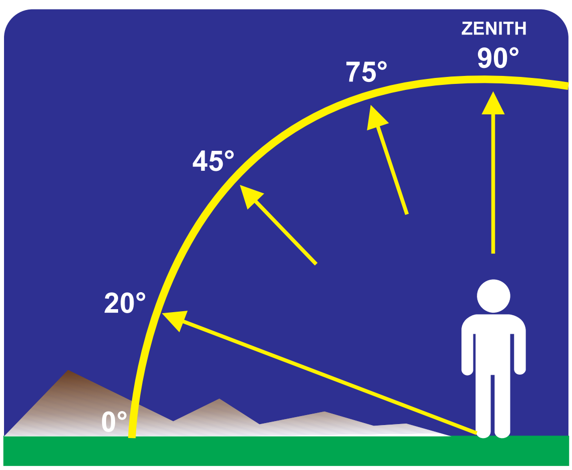
the bottom control panel one can observe the apparent movement of stars in the sky, fast-forwarded in time.

The duration of a day and night cycle is based on how long it takes for celestial objects to return to their starting position. Interestingly, this duration of day-night is different if we choose a nearby object like the Sun as our reference, as opposed to the more distant stars.

This can be investigated with the following exercise, which requires some careful manipulation of the software.

For this exercise, the students would need to know two concepts:

(a) What "altitude" means.



(b) How angles are subdivided into minutes and seconds?

Altitude is a measure of how high or how low an object is with reference to our horizon. A star that is just rising from the Eastern horizon has an altitude of 0 degrees. A star that is setting at West also has an altitude of 0 degrees. A star that is directly above our head (called the zenith point) is at an altitude of 90 degrees. A star that has crossed the zenith has an altitude less than 90 degrees. The following figure illustrates the definition of the altitude angle.

Just as one hour is divided into sixty minutes, and a minute further into sixty seconds, angles that span less than a degree are divided into minutes and seconds. 1 minute is 1/60th of a degree, and one second is 1/60th of a minute. Instead of writing angles in decimal notation, it is common to express them in minutes and seconds. Thus

45.5 degrees is also written as 45 deg 30 minutes

60.73 degrees is also written as 60 deg 43 minutes and 48 seconds

Having understood the two concepts, one can proceed with the following exercise that will help one understand the definition of a day.

The daily period of the Sun

1. Select your observing location.
2. Pick any time (say 10:00 am) and a date of choice.
3. Pause time through the controls on the bottom panel. This step is very important, otherwise you may have difficulty carrying out the necessary observations.
4. Click on the image of the Sun on screen. STELLARIUM will display, among a host of other things, the altitude of Sun for that time.
5. Increase the time in steps of hours and find out how much time it takes for the Sun to return to the same altitude in the sky.
6. You will notice that the altitude of the Sun comes back to the starting value in approximately 24 hours. (There will be a small difference of a few arc minutes in angle. An arc minute is 1/60th of a degree and is a tiny measure of angle. This difference can therefore be ignored for the purpose of our exercise here)

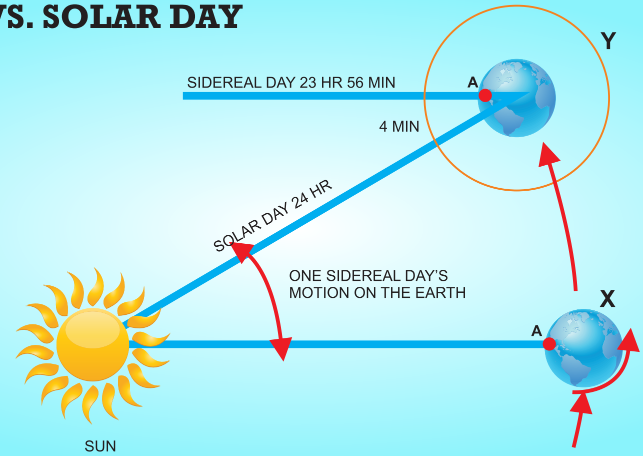
Thus, our current definition of a day-night cycle of 24 hours is based on the apparent daily motion of the Sun in the sky. 24 hours is the time it takes for the Sun to complete a full circle around Earth. (We perceive this relative motion coming from the rotation of Earth. The Sun does not go around Earth). 24 hours is the duration of a **solar day**, and this time system is called **solar time** or **civil time.**

The daily period of stars

Following the same steps as above, instead of picking the Sun, select a star (any star) visible at night.

1. Click on the image of the star. STELLARIUM will display the altitude of the star.
2. Increase the time in steps of hours and find out how long it takes for the star to return to the same altitude in the sky.
3. You will find that it takes not 24 hours, but only 23 hours and 56 minutes for the star to return

SIDEREAL DAY VS. SOLAR DAY



to the same position in the sky. In 24 hours, the star advances an extra 1 degree in altitude.

Thus, if instead of the Sun, we were to use any other star in the sky as the basis for our definition of a day-night cycle, the duration would be less than 24 hours. To be precise, the day-night cycle would be 23 hours and 56 minutes. This scheme of definition of a day-night cycle is called the **sidereal time.** "Sidereal" is a word with Latin roots and it means "in relation to the stars".

Since our everyday activities are so tightly linked to the rising and setting of the Sun, all the clocks that we use for our daily purposes are based on the solar day of 24 hours. Astronomers, in contrast, use sidereal time often because of their interest in objects beyond the Sun, which become accessible during the night.

The solar day is longer than the sidereal day because of Earth's revolution around the Sun.

The above illustration shows Earth spinning along its imaginary axis and at the same time orbiting the Sun. Imagine that point A on Earth corresponds to an observer's location. One needs a reference point in the sky against which the spin of the Earth can be measured. For example, how would one know whether Earth has completed a 360 degree rotation on its axis? Only if there is a reference point outside of the Earth, one can talk about the Earth's spin relative to it. This reference point can be the Sun, or more distant stars. This choice distinguishes the solar day from the sidereal day.

The time it takes for point A on Earth to spin 360 degrees with reference to distant stars is 23 hours and 56 minutes. During this time, stars return to their positions in the sky. But in that same time, the Earth moves ahead in its orbit around the Sun. By how much does the Earth move in one day?

The Earth takes 365 days to complete one full revolution of 360 degrees around the Sun. Thus, in one day Earth moves by approximately 1 degree in its orbit. This suggests that the Earth has to spin an extra 1 degree for the Sun to return to its prior position in the sky. To spin an extra 1 degree, Earth takes about 4 minutes, which explains the offset of 4 minutes between sidereal and solar days.

Conclusion

These are only a handful from the many exercises one can carry out using STELLARIUM. The software is highly resourceful. Its user's guide is a good reference in case you need help in navigating through the software. Many universities have created laboratory exercises using STELLARIUM. These can be accessed by searching the internet. As you become familiar with STELLARIUM's interactive features, you will be able to write your own exercises to explore further, the patterns and movements of the changing sky.

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