TUTORIAL 2

Class Assignment

1 Timekeeping

Have you wondered how clocks came into being? Everything in our lives today revolves around a universal definition of time, without which we cannot keep track of days, months and years. Timekeeping is a very fundamental requirement for the functioning of the modern world. However, it is an ancient concept that has evolved over many millennia. In the absence of advanced technology, the first clocks devised by people in the past relied on the cadence of the stars, the Sun and the Moon. Without the need to catch a train, finish an exam in time or work shifts in a factory, time was important for our forefathers in a different way: for basic needs such as eating and sleeping; for agricultural and migratory reasons that related to the seasons, as well as for religious purposes.

Let us explore a method of timekeeping by the well-known Mayan civilisation. The ancient Maya developed one of the most accurate calendar systems in human history. They were fascinated with cycles of time and were accomplished observers of the skies. The most commonly known Maya cyclical calendars are the Haab, the Tzolk'in, and the Calendar Round. Aside from these, the Maya also developed the Long Count calendar to chronologically date mythical and historical events.

THE MAYAN LONG COUNT CLAENDAR

If someone asked you what your date of birth was, you would probably answer them by giving a month, a day, and a year. But that's not the only way to record the past. Different cultures have used different calendar systems to mark time. One such system used by the Maya culture is called the Maya Long Count. In this exercise, you'll figure out your birth date using the Maya Long Count.

Most people today measure time in days, months, years, decades, and centuries, based on the Gregorian calendar system. The ancient Maya measured time in kins, uinals, katuns, and baktuns based on the Maya Long Count system. The numbers add up to the number of days since the beginning of the Maya Fourth Creation, which is calculated as August 11, 3114 BC, based on the Gregorian calendar.

Let's see how the Mayans would describe a day in the past: December 31, 1979. The Mayans record this day in the following form:

12.18.6.9.14

12:Baktun
18:Katun
6:Tun
9:Unial
14:Kin

So, if you're born on the 31st of December 1979, this is your date of birth according to the Mayans. Given below is an example with instructions on how this Mayan system works. You will also be guided by the teaching assistants.
Example: Date of birth: **20th June 1995**

First, calculate the total number of days that have passed since August 11, 3114 BC up to the day you were born. This is done in the following way:
1. Calculate all the whole years: Total number of years from 3113 BC to 1994 AD = 5107
2. Number of leap years from 3114 BC to 1994 AD = 1237
3. Total number of days (including leap years) = 1865292
This accounts for all the days from 1st January 3113 BC to 31st December 1994 AD. 4. Add the extra days, excluding the 11th August 3114 BC and 20th June 1995. This comes to 1865604 days.
5. Now all you have to do is play with your calculators. Just divide and multiply, over and over again. Look at the information below.

1 Baktun = 144,000 days
1 Katun = 7,200 days
1 Tun = 360 days
1 Unial = 20 days
1 Kin = 1 day

In this example, the number of days is N = 1865604
To obtain the Mayan Long Count date:
1. Divide N by one baktun. A1 = 12.9555833 Keep **12**
2. Multiply 0.9555833 with one baktun. A2 = 137604
3. Divide A2 by one katun. A3 = 19.1116666 Keep **19**
4. Multiply 0.1116666 with one katun. A4 = 804
5. Divide A4 by one tun. A5 = 2.23333 Keep **2**
6. Multiply 0.23333 with one tun. A6 = 84
7. Divide A6 by one uinal. A7 = 4.2 Keep **4**
8. Multiply 0.2 with one uinal. A8 = 4
9. Divide A6 by one kin. A9 = 4 Keep **4**

Combining these together, we have: **12.19.2.4.4**
In the same manner, calculate your date of birth according to the Mayan Long Count system.

2 Lunar Parallax

Hold up a finger and focus on something in the distant background. While looking at the background, alternately open your left and right eye, one at a time. You will find that your finger appears to have changed position. This is the parallax effect in action.

Figure 1: Parallax

Figure 2: Lunar parallax

Parallax is defined as the displacement in apparent position of an object when viewed from two different vantage points relative to a fixed distant background. The parallactic angle is measured as the angular separation between the apparent positions of the object relative to the background. One can also observe this effect when planets, comets and asteroids in our solar system are observed from different locations on Earth. In this case, the distant stars act as our background. This effect is more pronounced for nearby objects such as the Moon, as shown in Figure 2.

In Figure 2, the Moon is photographed simultaneously from two different locations on the Earth. Due to parallax, the Moon appears to have shifted with respect to the distant star. If the parallactic angle of the Moon is measured from two locations on Earth, then one can determine the distance to the Moon. Your task is to observe this lunar parallax from two locations and calculate the distance to the Moon.

Open Stellarium and follow the instructions below:
1. Set the date and time to 29/11/2017, 20:00.
2. Go to 'Location window' and change the location to Stockholm, Sweden.
3. Locate the Moon in the night sky and click on it. Note its RA and Dec coordinates.
4. Now change the location to Cape Town, South Africa. Repeat step 3.

You'll notice a difference in the RA and Dec coordinates of the Moon when viewed from Stockholm

and Cape Town. The change in coordinates of the Moon results from the parallax effect. Using a calculator, find the parallactic angle of the Moon.
The geometry of the parallax effect for the Moon is shown in Figure 3.
Let's call the Moon's parallactic angle a. The distance between Stockholm and Cape Town is about

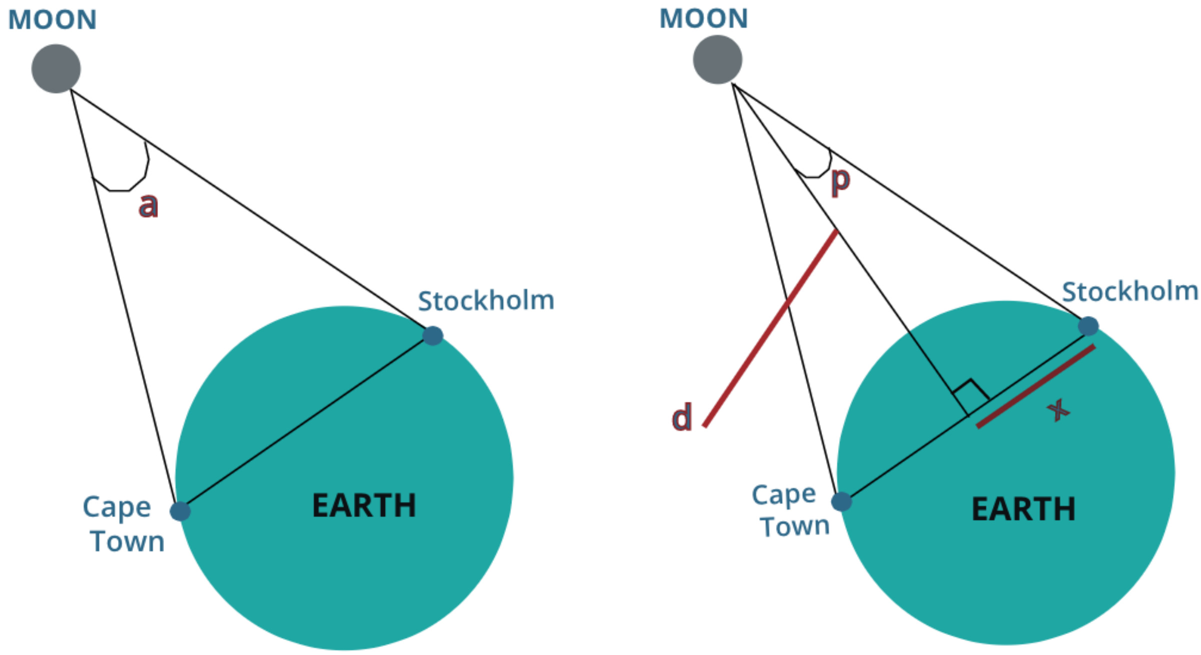

Figure 3: Geometry

9012 km. To find the distance to the Moon, we must split the triangle in Figure into two equal right angle triangles as shown in Figure. Here, the angle $p = a/2$ and the distance $x = 4506$ km. This is half the distance between Stockholm and Cape Town. To get the distance d to the Moon we use the following simple equation:

$$\tan(p) = \frac{x}{d} \tag{1}$$

Rearranging the terms in equation (1) we have:

$$d = \frac{x}{\tan(p)} \tag{2}$$

Fill in the values of x and p in equation (2) and calculate the value of d. The answer will have units of km. Compare this with the average distance to the Moon: 384,000 km. Discuss the possible reasons why your answer may be slightly different.

3 Blackbody Radiation

A so-called blackbody has a surface that absorbs all incident electromagnetic radiation, regardless of the frequency of the radiation. If one maintains a blackbody at a constant temperature, it would then emit electromagnetic radiation at all frequencies. In other words, a blackbody is a perfect absorber and a perfect emitter.

The radiation emitted by a blackbody is called blackbody radiation. This radiation is continuous in nature, meaning that photons of all wavelengths are emitted, while the intensity of the radiation at a particular wavelength depends only on the temperature of the blackbody. The German physicist

Max Planck, calculated the relationship between the temperature, wavelength and the amount of radiation emitted by a blackbody. This relationship is known as Planck's law and has a characteristic shape as shown in Figure 4. To learn more about blackbody radiation, start the animation on:

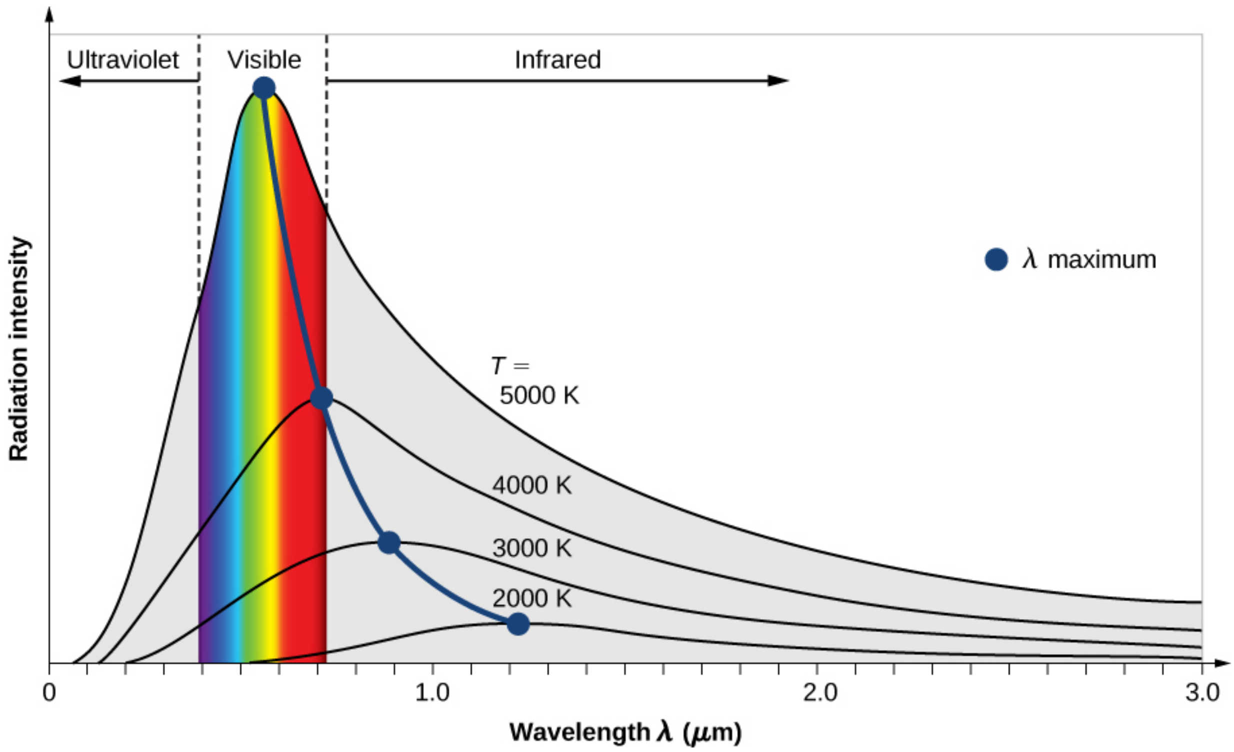

Figure 4: Spectrum of a blackbody

http://astro.unl.edu/naap/blackbody/animations/blackbody.html
To use the animation, follow the instructions given below:
1. Set the temperature to 10,000 K. Enable the 'highlight area' and 'indicate peak wavelength' boxes.
2. For the vertical scale, select the 'lock scale' option. For the horizontal scale, set the rightmost limit to 3μm.
3. Now, change the temperature from 10,000 K to 3000 K in suitable steps.
4. Note how the peak wavelength and area under the curve changes for different temperatures.
Using the simulator, answer the following questions:
Q1. For any temperature, does the blackbody radiation curve have a peak? If so, is the curve symmetric about this peak?

Q2. Set the temperature to 6000 K. Use the 'add curve' feature to plot two curves simultaneously. Vary the temperature of the second curve. Can you find a blackbody curve of another temperature that intersects the 6000 K curve?

Q3. Use 'remove curve' feature to make sure there is only one curve present. Check the 'indicate peak wavelength' box. For different temperatures, note how the peak wavelength changes. Express this behaviour in a statement.

Q4. Check the 'highlight area' box. For different temperatures, note how the area under the curve changes. Express this behaviour in a statement.

In reality, there is no such thing as an ideal blackbody. However, any object with a temperature above absolute zero emits electromagnetic radiation. It is called thermal radiation. The spectrum of thermal radiation of a body can be approximated by a blackbody spectrum.