Exercises

The Sun

1. Draw a picture to prove that the altitude of the celestial pole equals the latitude of the observer.
2. Start a virtual planetarium at sunrise on a random day and then follow the azimuth of the sun at rising up to a solstice and then back again.
3. Today you are in Rome, at dawn, looking at an azimuth of 96°. You see the sun rising from behind a hill which is 10° high. Establish the day(s).
4. Draw a picture to convince yourself that the presence of a hill at the eastern horizon increases the azimuth of sunrise with respect to that corresponding to a flat horizon. What happens to the azimuth of sunset if another hill is placed at the western horizon?
5. Determine the azimuth of the rising sun at the summer solstice in the following cities: Cairo, Milan, London, Stockholm, Quito, Cusco, Santiago, with a flat horizon. How does this azimuth change if the horizon is 5° high?
6. Determine on how many days the sun casts shadows from the north in the following cities: New York, Lima, Mexico City, Buenos Aires, Quito.
7. Determine the Julian date of the summer solstice in AD 400 and in AD 1400, and the proleptic Julian date of the winter solstice in 1000 BC.
8. At a certain place the latitude is equal to L degrees. In the days of the zenith passages of the sun the declination of the sun is D. How much is L-D?

The Stars

1. Determine azimuth and date of the Heliacal rising of Aldebaran in Cairo. Do the same for Milan, London, Cusco, Rio de Janeiro. Estimate the period of invisibility. Solve the same problem for Canopus and for the Pleiades.
2. Determine the latitude at which the seven stars of the big Dipper cease to be circumpolar in the northern hemisphere today. The same in the seventh century BC. Try to explain why Homer says that the Big Dipper "never bathes in the sea".

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3. Determine at which latitude the star alpha of the constellation Centaur is visible today in the northern hemisphere.
4. Try to define the heliacal rising of a zodiacal constellation as a whole. Do you think it is a meaningful concept? Consider the same question for the Pleiades.

Precession

1. You are in Cairo, and see Sirius rising during the night with the azimuth 108° on a flat horizon. Establish which century you are living in.
2. You see the sun at the spring equinox rising close to the star alpha of Aries. Establish which century you are living in.
3. Determine the constellation in the background of the winter solstice sun: today, in the first century BC, in 2500 BC, in 10000 BC. The same for the spring equinox. Does the result depend on the position of the observer?
4. Does the day of Heliacal rising of a star at a fixed latitude change with precession? Explain your answer fully.
5. Determine the declination of Sirius in 2700 BC. Estimate the date of the Heliacal rising of this star at the latitudes of Cairo and of Aswan at that time.
6. Discuss whether Vega has ever been a "Pole Star". The same for Deneb.
7. Define a concept of "south pole star" and establish if there is any naked-eye visible star in the sky which may become, or may have been, such a star.
8. There is a point in the northern sky which is a true, invariable pole. However, it is not located close to any visible star. Why is there such a point? Where is it? What about the southern hemisphere?

Moon and Venus

1. Start a virtual planetarium in a day of year 2000 and follow the behaviour of the Moon at the horizon for a couple of lunar months. Notice the corresponding declinations and the phases of the Moon. Once you are acquainted with this, analyse the behaviour of the Moon in December and in June 2006.
2. You are asked to define, in analogy with the tropics, the concept of "lunar tropics". Where do you think they should be located? Why? Explain analogies and differences with the solar tropics.
3. At which latitude is the Moon at the major northern standstill circumpolar? Explain the result.
4. Start a virtual planetarium on a random day and search for Venus, establishing in which part of her synodic period is situated. Then follow the behaviour of the planet at intervals of a few days for one entire cycle. Concentrate your analysis close to the days of disappearance and reappearance of the planet.

5. Start a virtual planetarium on November 5, 2005. Verify that Venus is going to attain the minimal declination. When do you think that the maximal declination will be attained? Check your hypothesis.

Statistics

1. In a necropolis located in a flat area where the azimuth of the winter solstice is 120°, the azimuths of 35 tombs' corridors are measured, and 12 of them fall into the sector of azimuths of the sun climbing in the sky.
   - Find the probability p that one azimuth is by chance located in this sector
   - Find the probability that 12 azimuths are by chance located in this sector
   - Find the mean and the standard deviation of the distribution
   - Find the sigma level we are working with. Can we claim that the orientations are definitely astronomical?
2. After a measurement, 21 out of 40 Roman towns based on a orthogonal grid turn out to be orientated within ±2° from the cardinal points. Can we claim that the orientation was deliberate? With what degree of confidence?

Virtual Fieldwork

The exercises below are based on important monuments and sites. Before addressing them, readers should acquaint themselves with the basics on the corresponding historical period.

1. Using Google Earth and a Sky Globe software, analyse:
   - The orientation of the Milan cathedral.
   - The orientation of the Chartres cathedral.
   - The orientation of Notre Dame in Paris.
2. Using Google Earth and a Sky Globe software, analyze:
   - The orientation of the Roman town of Merida, Spain.
   - The orientation of the Roman town of Verona, Italy.
   - The orientation of the Roman town of Timgad, Algeria.
3. Using Google Earth and a Sky Globe software, analyse the orientation of the Parthenon in Athens.
   - Do you think that a solar hypothesis is feasible?
   - Try to formulate a alternative stellar hypothesis.

4. Locate the Nasca drainage plain on Google Earth. Then:
   - Become aware that it is a desert but that nearby zones towards the coast are fertile, so people could easily walk around. Have a look at the horizon profiles.
   - Locate the modern Pan-American highway and search for zoomorphic geoglyphs around it. Try to locate at least five geoglyphs including the so-called monkey, spider, and cormorant.
   - Try to define a symmetry axis for each of the figures. How many azimuths would you measure in fieldwork? Measure the same azimuths and horizon altitudes with Google Earth and create a virtual fieldwork notebook.
   - Analyse the corresponding sky in the first centuries AD. Would you suggest an astronomical orientation for the figures?
5. Locate the Hopewell earthworks called Great Circle and Octagon of Newark (Licking County, Ohio) on Google Earth (the Octagon is easy to find as it is used as a Golf course). Then:
   - Measure the axis of Octagon-circle earthworks and the sight lines defined by two sides of the Octagon and by one corner-to-corner line point. Try to determine whether the corresponding horizon is/was flat in the first centuries AD. Are there other lines to be measured to avoid selection effects?
   - Determine the azimuths of the sun at the solstices and those of the Moon at the lunar standstills at Newark and compare them with the results above. Do you think that the project of the earthworks was based on the moon positions at the horizon or that your results were obtained by chance?