International School for Young Astronomers 2016

August 2016

Astronomical Techniques: Assignment 1

General Instructions

(1) You should try to obtain solutions to these questions by yourself. The less you talk to others, the more you will learn. But if you are really stuck after a sincere effort, talking to your friends may be helpful. (2) Most of the questions test a single concept introduced in class. For such questions, your answer should not be longer than 5-10 lines. (3) I have tried to make the questions unambiguous and correct. But if you suspect that there is any error /ambiguity, feel free to say so in your answers. For a few problems, you may need to look up relevant numbers in the appropriate reference books or online. Please retain the correct number of significant figures in your answers. (4) Those who submit answers to these problems by Wednesday, 31 August 6 pm, will get their sheets corrected and returned on Saturday, 3 September.

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(1) Calculate the length of the sidereal day on Earth. What would be the length of the solar and sidereal days, in the current time measures (our solar hours, minutes and seconds), if the Earth would rotate in the opposite direction, but with the same rotation speed?

(2) What is the minimum flying distance from Tehran to Mumbai if your plane flies at an altitude of 10 km? You should assume that the earth is a sphere for this question.

(3) With a 5 cm telescope, under excellent seeing conditions, what is the diameter of the smallest crater you can resolve on the moon?

(4) Suppose you have a solar panel with an area of 1 sq. metre. If it operates with an efficiency of 20% what is the maximum power that it can generate on Earth? and on Mars?

(5) Assume that you are living in the time of Copernicus and do not know anything about Kepler's laws. You might calculate Mars-Sun distance in the same way as he did. After accepting the revolutionary belief that all the planets are orbiting around the Sun, not around the Earth, in circular orbits, you measure that the orbital period of Mars is 687 days, then you observe that 106 days after opposition of Mars, the planet appears in quadrature (Sun-Earth-Mars form a right angled triangle with right angle at Earth). Calculate Mars-Sun distance in astronomical units (au).

(6) A house located in Pune, India has one of its walls facing due North. Every year, during what date range will this wall be directly illuminated at local noon by the sun? Will these dates change from year to year? (Hint: consult the Astronomical Almanac for the declination of the Sun)

(7) Imagine that on 21 March 2010, you find yourself marooned on a sandy beach of an uninhabited island in the middle of the ocean. The sun is just rising. By sunset, you need to determine the latitude and longitude of your location. The vegetation on the island indicates that you are at temperate latitudes. All you have with you is a wooden stick (about 2m long), an accurate watch showing Iranian Standard time in 24hr format, a measuring tape about 10 m long graduated in centimetres. Explain clearly how how you will determine your location. Draw an appropriate figure.

(8) A selenelion or selenehelion occurs when both the Sun and a fully eclipsed Moon can be observed at the same time from specific locations on the earth. Under what conditions is this possible? Why is it easier seen at sea than on land?

(9) The pole star Polaris has 2000 AD Epoch equatorial coordinates of RA 02:3:49.08 and Dec. +89:15:50.8. Determine its precessed coordinates for 2100 AD Epoch. You should use an appropriate computer program to do this.

(10) Explain how timing transits of Venus from two well separated locations on Earth can be used to determine the value of an astronomical unit (AU) in km.

(11) While photographing a landscape scene with your digital camera under bright sunlight, you find that a 1/30 second exposure is needed for an aperture setting of f/16. If you were to photograph the same scene in the light of a full moon, what would be the exposure with an aperture setting of f/8? What would be the color of a clear sky in such a photograph taken in moonlight and why?

(12) You have placed a detector with 10μm pixels at the prime focus of a 2m diameter f/10 telescope? What will be the separation in detector pixels of two stars 10 arcsec apart?

(13) Determine the hour angle of the star Sirius when observed at midnight from the Iranian National Observatory (IGO) on 10 March 2016.

(14) What is the airmass of the star Sirius as seen from the Iranian National Observatory, on 15 January 2016 at midnight Iranian Standard time?

(15) The Megacam camera used for CFHT Legacy survey has a field of view of 0.92 sq. deg. It contains 40 identical 2048 x 4612 CCDs. If the focal length of the telescope used is 15 m, compute the pixel size (in microns) of the CCDs used in this camera.

(16) A drift scanning telescope tracks the sky at the sidereal rate. If the pixel scale of the CCD detector is 0.4 arcsec/pixel and the CCD has 2048×2048 pixels, what is the effective exposure time on the sky? Which major sky survey do these parameters correspond to?

(17) The refractive index η of air at sea level at 15 degrees C is given by:

$$(\eta - 1) \times 10^8 = 8342 + \frac{2.4 \times 10^6}{130 - \lambda^{-2}} + \frac{1.6 \times 10^4}{40 - \lambda^{-2}}$$

where λ is the wavelength measured in microns. Calculate the angle by which the position of a star appears to shift, as measured at 0.5 microns, as a function of airmass. You may assume that the atmosphere is a single slab of constant density. Note η is very close to unity, so an expansion in the quantity $\eta - 1$ to first order will make the algebra much easier.

(18) Suppose you are observing with the Sloan Digital Sky Survey imaging camera, whose field of view has a diameter of 3 degrees. If the camera is observing the sky at an airmass of 1.4, what is the differential atmospheric refraction from one side of the camera to the other, at 5000Å ?

(19) There is also chromatic atmospheric refraction, caused by the wavelength dependence of η. Expand the expression above to first order in λ^{-2}. Compute the difference in the position of a star observed at an airmass of 2.0, at wavelengths of 4000Å (blue light) and 7000Å (red light). Is the effect large enough to be measureable?

(20) If the optics of a telescope are diffraction limited, then its angular resolution is given by the diameter of the Airy disc $A = 1.22\lambda/D$ where λ is the wavelength of observation and D is the diameter of the objective in the same units. At $\lambda = 5000$Å the resolution of the human eye is about 4 arcminutes. If a telescope of diameter D meters is to be used visually, what magnification should be used to place it at the diffraction limit?

(21) A digital camera is used with a aperture setting of $f/16$ at visual wavelengths. What pixel size (in microns) would result in the highest possible resolution?

(22) The surface brightness of an extended source like a galaxy or nebula does not change when viewed with the naked eye instead of through a telescope. Nevertheless, real experience shows that extended objects like the Andromeda galaxy or the Orion nebula are brighter when viewed with a telescope as compared the naked eye. Can you explain how this is possible?

(23) On a visit to the southern hemisphere, you contemplate the rise of the south ecliptic pole and wonder how fun it would be if the sky started spinning around the ecliptic pole, instead of the usual celestial pole. Sketch your displacement over the Earth's surface, to observe the stars revolving around the south ecliptic pole in the same direction and with the same period that they usually revolve around the south celestial pole. Sketch your trajectory for one entire day. Determine your velocity (direction and speed) when crossing the Equator for the first time.