MyAO Finals 2022: Theory Round

Each problem is worth 10 points. Problems are not sorted by difficulty.

1. On 13 th June 1991, from Segamat, Johor (2.5° N, 102.82° E), The Moon appears to be at an altitude of 43°, and azimuth (measured from the north) 103°. Meanwhile Jupiter was at altitude 59°, azimuth 88°.

   (a) Are the objects rising or setting?

   (b) How far apart did the two planets appear? In other words, calculate the angular separation between the Moon and Jupiter as seen from Segamat at that moment.

   The spherical law of cosines might be useful: For a spherical triangle with lengths a, b, c and the angle opposite c is C we have

   $$\cos c = \cos a \cos b + \sin a \sin b \cos C$$

2. Sometime in the far future, a probe of mass $m = 1.0 \times 10^3$ kg reached an exoplanet of mass $M = 2.0 \times 10^{24}$ kg. The probe was inserted into an elliptical orbit around the exoplanet with eccentricity $e = 0.80$ and semi-major axis $a_1 = 3.0 \times 10^5$ km. When the probe is at periapsis, it can decelerate due to the friction between its adjustable panels and the exoplanet atmosphere, causing a decrease in velocity anywhere from 1.0 km s^{-1} to 3.0 km s^{-1}. After n periapsis flybys, the probe fires its engines at apoapsis and accelerates to a stable circular orbit with semi-major axis $a_2 = 7.0 \times 10^4$ km. Find minimum n so that this can be achieved. Assume that the changes in velocity at periapsis and apoapsis occur instantaneously.

3. Using a telescope and spectrograph, we can record the spectrum of Saturn as well as the spectrum of the A ring. We find that light from one outer edge of the A ring is redshifted and light from the other outer edge is blueshifted. If we are observing a spectral line at the wavelength of 550 nm, what is the difference in wavelength between the opposite edges of the A ring? (Note: The radius of the outer edge of the A ring is 136,500 km. The particles at the outer edge of the A ring take 14 hours 30 minutes to make an orbit around Saturn)

4. If you are observing the Earth transiting the Sun from Mars, how long would you expect the transit to occur?

5. Stars A and B revolve around their common centre of mass (COM) in circular orbits with a 5 year period. Star A has a surface temperature $T_A = 4,000$ K, radius $R_A = 3.0 \times 10^7$ km and mass $M_A = 2.0 \times 10^{30}$ kg. Star B has a surface temperature $T_B = 10,000$ K, radius $R_B = 1.0 \times 10^6$ km and mass $M_B = 4.0 \times 10^{30}$ kg. Point C is a point on the line segment joining A and B that has the minimum total flux from A and B. Find the distance between point C and the centre of mass.

6. The distance between the objective lens and the eyepiece lens of a refracting telescope is 58 cm. The overall magnification of the telescope when the eye is relaxed is 124X. Calculate the focal length of eyepiece lens (f_{eye}) and the focal length of objective lens (f_{ob})

7. An astronomer observed an orange star with a peak wavelength $\lambda = 700$ nm and apparent visual magnitude of 11.0. The star then exploded as a Type Ia supernova with an apparent visual magnitude of -7.0. Type Ia supernovae have a typical absolute visual magnitude near -19.3. Find the radius of the orange star in terms of the solar radius $R_{\text{Sun}} = 6.96 \times 10^5$ km. (The Sun has an absolute visual magnitude of 4.83 and luminosity $L = 3.828 \times 10^{26}$ W.)

8. Sketch the Milky Way Galaxy in cross section as seen edge-on. In the sketch include the disk, nucleus, Sun, visible halo and some globular clusters. Also include the various dimensions of the Milky Way Galaxy.

9. The James Webb Space Telescope (JWST) has been launched successfully into space into the Sun-Earth L2 Lagrangian Point and is currently under calibration and testing. This telescope will be ready to capture good astronomical data by June 2022. This most powerful infrared space telescope will be a giant leap forward in our quest to understand the Universe and our origins. Give THREE reasons why JWST could solve deep mysteries in cosmology.

10. As of 29 April 2022, 5,014 exoplanets have been discovered by astronomers. Exoplanets are planets that are orbiting other stars in the Milky Way Galaxy. The first three exoplanets were only discovered in 1992 orbiting the pulsar PSR 1257+12 in the constellation of VIRGO. Give THREE reasons why it is difficult to detect and discover exoplanets.