Astronomy Variant Question Set

Prepared by Salkaro

The Night Sky

Question 1: Stellar Triangulation

Two observatories at latitude 40°N measure the position of an asteroid simultaneously. Their longitudes differ by 6.0°, giving a baseline of 667 km. The asteroids apparent positions differ by 48″. Assuming the baseline is perpendicular to the line of sight, compute the asteroids distance in km.

Question 2: Parallax Distance and Absolute Magnitude

A nearby star has apparent magnitude $m = 7.6$ and parallax $p = 0.042''$.

1. Compute its distance in parsecs.
2. Determine its absolute magnitude M.

Question 3: Magnitude and Flux Ratio

Two variable stars A and B lie in the same cluster at distance 1.8 kpc. Star A brightens from $m = 12.0$ to $m = 11.2$. Star B dims from $m = 10.5$ to $m = 11.0$. Compute the ratio of the new flux of star A to the new flux of star B.

Question 4: Constellation Visibility at Given Latitude

An observer at latitude $+52°$ wishes to know whether a star of declination $-18°$ is ever visible.

1. Determine whether the star rises above the horizon.
2. If it does, compute its maximum altitude when crossing the meridian.

Question 5: Solar Altitude on a Solstice

At latitude $+35°$, compute the Suns maximum altitude:

1. on the summer solstice,
2. on the winter solstice.

Assume Earths axial tilt is $23.5°$.

Question 6: RADec and Meridian Crossing Time

A star has coordinates RA $= 05^{\mathrm{h}}18^{\mathrm{m}}$, Dec $= +22°$. On February 10, the Suns RA is approximately 21^{h}. Estimate the local sidereal time at midnight and determine the clock time when the star crosses the meridian.

Question 7: Atmospheric Refraction Shift

A star at true altitude $12°$ experiences atmospheric refraction approximated by $r = \frac{1.02°}{\tan(h+10.3°/(h+5.11°))}$ where h is the true altitude in degrees and r is in arcminutes. Compute the apparent altitude of the star.

Question 8: Sidereal vs Solar Day Timing

A star rises at 22:16 local time on March 1. Assuming the sidereal day is 23h 56m, determine the rise time of the same star on March 15.

Question 9: Lunar SynodicSidereal Relation

The Earths orbital period is $P_{\text{year}} = 365.25$ days. Using the relation

$$\frac{1}{P_{\text{sid}}} - \frac{1}{P_{\text{syn}}} = \frac{1}{P_{\text{year}}},$$

an astronomer measures the synodic period of a moon around a distant exoplanet to be $P_{\text{syn}} = 34.7$ hr. Compute the moons sidereal period in hours.

Question 10: Eclipse Geometry and Angular Sizes

A moon of radius 1800 km orbits its planet at distance 4.9×10^5 km. Its star has radius 6.2×10^5 km and lies 1.4×10^8 km from the planet.

1. Compute the angular sizes of the star and moon as seen from the planet.
2. Determine whether a total or annular eclipse occurs when the moon passes directly in front of the star.

Question 11: Planetary Synodic Period and Opposition

A newly discovered asteroid has sidereal period 4.21 years.

1. Compute its synodic period with respect to Earth.
2. Determine how many days elapse between successive oppositions.

Question 12: Meteoroid Impact Rate Estimate

A meteoroid stream has spatial density 4.0×10^{-8} m^{-3}. Earth sweeps through the stream at $v = 29.8$ km/s over a cross-sectional area $\pi R_{\oplus}^2$ with $R_{\oplus} = 6370$ km. Estimate the number of meteoroids entering Earths atmosphere per second during the peak of the shower.

The Solar System

Question 1: Orbital Geometry and Inferior Conjunction

A newly discovered inner planet has a synodic period of 142 days as seen from Earth. Assuming circular, coplanar orbits and $P_E = 365.25$ days, determine

1. the planets sidereal period,
2. its orbital radius in AU.

Question 2: Keplerian Mass Determination in Binary Motion

A small moon orbits a dwarf planet in a circular orbit of radius 880 km with period $P = 11.3$ hr. Determine

1. the mass of the dwarf planet,
2. the escape velocity from its surface if its radius is $R = 420$ km.

Question 3: Atmospheric Scale Height on a Terrestrial World

A rocky planet has surface gravity $g = 6.1$ m s^{-2} and atmospheric temperature $T = 295$ K. Its atmosphere is dominated by nitrogen ($m = 4.65 \times 10^{-26}$ kg). Calculate

1. the scale height H,
2. the pressure at altitude $z = 42$ km if the surface pressure is $P_0 = 0.89$ bar.

Question 4: Solar Insolation and Equilibrium Temperature

A planet orbits a Sun-like star at 2.35 AU and has Bond albedo $A = 0.27$. Assuming blackbody equilibrium with uniform heat redistribution, compute the planets equilibrium temperature.

Question 5: Rotation and Oblateness of a Giant Planet

A gas giant of radius $R = 6.4 \times 10^7$ m rotates once every $P = 8.1$ hr. Assume hydrostatic balance and use the approximation

$$f \approx \frac{3R^3}{2GMP^2}$$

for the flattening $f = (R_{\rm eq} - R_{\rm pol})/R_{\rm eq}$. If the planets mass is $M = 1.9 \times 10^{27}$ kg, compute its flattening.

Question 6: Surface Cratering and Age Estimation

A region on an icy moon shows 185 craters larger than 5 km across per million square kilometers. If the external impact flux for bodies of that size is $F = 7.5 \times 10^{-15}\ \mathrm{km^{-2}yr^{-1}}$, estimate the surface age of the region.

Question 7: Ring Particle Orbit and Resonances

A ring particle orbits a giant planet at radius 1.42×10^5 km with period $P_r = 0.62$ days. A nearby moon has orbital radius 2.31×10^5 km and period $P_m = 1.82$ days. Determine whether the ring location corresponds to a $2:1$ or $3:1$ mean-motion resonance with the moon.

Question 8: Meteoroid Ablation and Energy Deposition

A stony meteoroid of mass $m = 180$ kg enters an atmosphere at $v = 17.5$ km s^{-1}. Assuming 85% of its kinetic energy is deposited as thermal energy in the air, compute

1. the total deposited energy in joules,
2. the equivalent energy in tons of TNT (1 ton TNT $= 4.184 \times 10^9$ J).

Question 9: Cometary Outgassing and Non-Gravitational Acceleration

A comet nucleus of mass $M = 3.4 \times 10^{12}$ kg experiences a measured non-gravitational acceleration

$$a_{\text{ng}} = 2.6 \times 10^{-7} \text{ m s}^{-2}.$$

If the gas outflow speed is $u = 620$ m s^{-1}, estimate the required mass-loss rate $\dot{M}$ assuming thrust $T = \dot{M}u = Ma_{\text{ng}}$.

Question 10: Protoplanetary Disk and Accretion Timescale

At 3 AU in a young disk, the solid surface density is $\Sigma_s = 5.2$ kg m^{-2}. Planetesimals of radius $r = 7.0$ km and density 1400 kg m^{-3} grow by sweeping up material with gravitational focusing factor $F_g = 18$. If the orbital period is $P = 5.2$ years, estimate the mass-doubling timescale for an individual planetesimal.