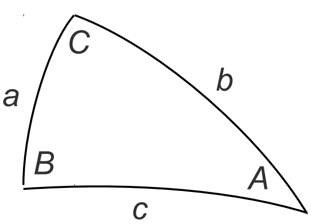
Astronomical and physical constants

Astronomical unit (AU)	1.4960×10^{11} m
Light year (ly)	9.4605×10^{15} m = 63 240 AU
Parsec (pc)	3.0860×10^{16} m = 206 265 AU
1 Sidereal year	365.2564 solar days
1 Tropical year	365.2422 solar days
1 Calendar year	365.2425 solar days
1 Sidereal day	$23^h\ 56^m\ 04^s.091$
1 Solar day	$24^h\ 03^m\ 56^s.555$ units of sidereal time
Mass of Earth	5.9736×10^{24} kg
Mean radius of Earth	6.371×10^{6} m
Equatorial radius of Earth	6.378×10^{6} m
Mean velocity of Earth on its orbit	29.783 km s^{-1}
Mass of Moon	7.3490×10^{22} kg
Radius of Moon	1.737×10^{6} m
Mean Earth – Moon distance	3.844×10^{8} m
Mass of Sun	1.98892×10^{30} kg
Radius of Sun	6.96×10^{8} m
Effective temperature of the Sun	5 780 K
Luminosity of the Sun	3.96×10^{26} J s^{-1}
Solar constant	1366 W m^{-2}
Brightness of the Sun in V-band	−26.8 mag.
Absolute brightness of the Sun in V-band	4.75 mag.
Absolute bolometric brightness of Sun	4.72 mag.
Angular diameter of the Sun	30′
Speed of light in vacuum (c)	2.9979×10^{8} m s^{-1}
Gravitational constant (G)	6.6738×10^{-11} N m^2 kg^{-2}
Boltzmann constant (k)	1.381×10^{-23} m kg s^{-2} K^{-1}
Stefan−Boltzmann constant (σ)	5.6704×10^{-8} kg s^{-3} K^{-4}
Planck constant (h)	6.6261×10^{-34} J s
Wien's constant (b)	2.8978×10^{-3} m K
Hubble constant (H_0)	70 km s^{-1} Mpc^{-1}
electron charge (e)	1.602×10^{-19} C
Current inclination of the ecliptic (ε)	23º 26.3′
Coordinates of the northern ecliptic pole for epoch 2000.0 (α_E, δ_E)	$18^h\ 00^m\ 00^s$, + 66º 33.6′
Coordinates of the northern galactic pole for epoch 2000.0 (α_G, δ_G)	$12^h\ 51^m$, + 27º 08′

You can try to solve an equation $x = f(x)$ using iteration: $x_{n+1} = f(x_n)$.



Basic equations of spherical trigonometry

$$\sin a \sin B = \sin b \sin A\ ,$$
$$\sin a \cos B = \cos b \sin c - \sin b \cos c \cos A\ ,$$
$$\cos a = \cos b \cos c + \sin b \sin c \cos A\ .$$

Long theoretical questions

Instructions

1. You will receive in your envelope an English and native language version of the questions.

2. You have 5 hours to solve 15 short (tasks 1-15) and 3 long tasks.

3. You can use only the pen given on the desk.

4. The solutions of each task should be written on the answer sheets, starting each question on a new page. Only the answer sheets will be assessed.

5. You may use the blank sheets for additional working. These work sheets will not be assessed

6. At the top of each page you should put down your code and task number.

7. If solution exceeds one page, please number the pages for each task.

8. Draw a box around your final answer.

9. Numerical results should be given with appropriate number of significant digits with units.

10. You should use SI or units commonly used in astronomy. Points will be deducted if there is a lack of units or inappropriate number of significant digits.

11. At the end of test, all sheets of papers should be put into the envelope and left on the desk.

12. In your solution please write down each step and partial result.

Long theoretical questions (max 30 points each)

1. A transit of duration 180 minutes was observed for a planet which orbits the star HD209458 with a period of 84 hours. The Doppler shift of absorption lines arising in the planet's atmosphere was also measured, corresponding to a difference in radial velocity of 30 km/s (with respect to observer) between the beginning and the end of the transit. Assuming a circular orbit exactly edge-on to the observer, find the approximate radius and mass of the star and the radius of the orbit of the planet.

2. Within the field of a galaxy cluster at a redshift of $z = 0.500$, a galaxy which looks like a normal elliptical is observed, with an apparent magnitude in the *B* filter $m_B = 20.40$ mag.

   The luminosity distance corresponding to a redshift of $z = 0.500$ is $d_L = 2754$ Mpc.

   The spectral energy distribution (SED) of elliptical galaxies in the wavelength range 250 nm to 500 nm is adequately approximated by the formula:

   $$L_\lambda(\lambda) \propto \lambda^4$$

   (i.e., the spectral density of the object's luminosity, known also as the monochromatic luminosity, is proportional to λ^4.)

   a) What is the absolute magnitude of this galaxy in the *B* filter ?

   b) Can it be a member of this cluster? (write YES or NO alongside your final calculation)

   Hints: Try to establish a relation that describe the dependence of the spectral density of flux on distance for small wavelength interval. Normal elliptical galaxies have maximum absolute magnitude equal to -22 mag.

3. The planetarium program 'Guide' gives the following data for two solar mass stars:

Star	1	2
Right Ascension	$14^h 29^m 44.95^s$	$14^h 39^m 39.39^s$
Declination	–62º 40′ 46.14″	–60 50′ 22.10″
Distance	1.2953 pc	1.3475 pc
Proper motion in R.A.	–3.776 arcsec / year	–3.600 arcsec / year
Proper motion in Dec.	0.95 arcsec / year	0.77 arcsec / year

Based on these data, determine whether these stars form a gravitationally bound system. Assume the stars are on the main sequence. Write YES of bound or NO if not bound alongside your final calculation.

Note: the proper motion in R.A. has been corrected for the declination of the stars.