Theory - Finale of the Junior Astronomy Olympiad 2026

The Swedish Astronomical Youth Associations Olympiad group

11 April 2026
10:30 to 14:30

This is the theoritcal part of the final exam for the Swedish Junior Astronomy Olympiad 2026. The 5 participants with the highest scores will be offered a place on the Swedish team in the *International Olympiad on Astronomy & Astrophysics Jr* (IOAA Jr) in Thailand, in November.

Good luck!

Name	

The exam begins on the next page. Do not turn the page until the clock strikes 10:30. Stop writing immediately when the clock strikes 14:30.

The exam consists of a total of 10 questions, both short and long. After each question, the possible score is indicated. The total score for the exam is 50 points. For *all* questions, a detailed answer with reasoning is expected for full points. Partially correct solutions will receive partial credit.

Allowed tools:
Writing utensils, paper, calculator, **no personal formula sheet** (except for the last page of the exam paper).

I have answered the following questions (cross):

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

1 Flhugo Berg (2p)

Omar observes a glowing fly at a considerable distance from his telescope. The observed apparent magnitude is 25 magnitudes lower than the sun.

Figur 1: Source: https://cybernews.com/science/china-send-fruit-fly-space/

How far away must a **type Ia supernova** be from the observer to have the same magnitude as the fly?

2 Zikais Telescopes (3p)

Zikai has a telescope at home that has a field of view of 1.35°; the telescope's eyepiece has a field of view of 65°.
a) What is the magnification of the telescope?
b) You are told that the focal length of the telescope's objective is 1.2 meters. What is the focal length of the eyepiece? Answer in millimeters.

3 Main Sequence Stars (3p)

How many times more light does a main-sequence star with a surface temperature of 15 000 K emit compared to a main-sequence star with a surface temperature of 5 000 K? Use the HR diagram in the formula sheet at the end of the test.

4 Västerberg's asteroid (4p)

Anders Västerberg talks about his asteroid 15311 Västerberg, which orbits the Sun with orbital data as shown below. The asteroid is observed from Earth to lie along the same line as the Earth and the Sun. At this moment, the distance between the Sun and the asteroid has decreased to 1.83 AU, after which it begins to increase.

To study the motion more closely, you leave the Earth and place yourself in space at exactly the point where the Earth was at the time of observation.
After a bit less than a year, the asteroid has moved one quarter of its orbit from its original position, while the observer remains.
Determine the distance between you and the asteroid.

Orbit	
Epoch	17 October 2024
Semi-major axis	2.2531 AU
Sidereal period	1235.3 d (3.38 years)
Inclination	1.330°

Figur 2: Source: Wikipedia

5 Where's the midnight Sun? (4p)

Vi befinner oss i Norrköping vid koordinaterna 58°35' N We are located in Norrköping at the coordinates $58° \ 35' \ N$, $16°10' \ \ddot{O}$, and the Sun's declination today (11/4-2026) is $8° \ 20'$. Mostafa realizes that he wants to experience **the midnight sun**, and therefore plans to travel from here. In which cardinal direction should he travel, and what is the minimum distance he must go to experience the midnight sun tomorrow? Assume he travels along the Earth's surface following the shortest path *"as the crow flies"*. You may neglect the Earth's motion around the Sun during one day. Give your answer in kilometers.

6 Polynova (4p)

Omar analyses the system AOJR26, which consists of two binary stars with a parallax of 6.7"in a nearly circular orbit. HE observes that the system spans 0.32' across the sky, and star 1 is approximately 2.3% more massive than star 2. If star 1 is Sun-like, what is the orbital period in years?

Figur 3: Credit: NOIRLab/NSF/AURA/J. da Silva (Spaceengine)/M. Zamani

7 So close yet so far (6p)

Viktor is searching for a binary star system using an optical telescope with a focal length of 1000 mm and an f-ratio of $f/5$. A certain system has a parallax of $0.05''$ as seen from Earth. Its two stars have masses of 12 and 8 $M_\odot$ and orbit each other with a period P of 3.0 years.Can the telescope resolve the two stars as separate objects so that Viktor finds what he is looking for?

8 Is this the rechts way? (6p)

Your friend Hugo Berg loves to travel and has now arrived at the hydrogen cloud Munich. He tells you that the cloud is moving with a total velocity of 500 km/s relative to Earth.

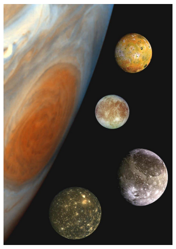
The cloud's parallax is $0.050''$. Over the course of one year, you observe that the cloud's right ascension does not change at all, but its declination changes by $0.025''$. The neutral hydrogen 21-cm line has a rest wavelength of 21.1 cm.

Determine the observed wavelength of this line if the cloud's radial velocity component is directed away from Earth. *Assume that the Doppler effect can be treated non-relativistically.*

9 Moona Lisa (8p)

Donililo Donile observes three of Jupiter's moons. At each observation, the moon's angular position θ along its orbit is measured, counted from an arbitrary reference direction in the orbital plane. The angle is given in degrees.

The observations extend over several days. Assume the orbits are circular and that the angular velocity is constant. Each angular measurement has an uncertainty of $\pm 5°$.



Source: Omar Wehbe, *Partikular*

Io

Time (days)	θ (°)
0.0	0
0.5	101
1.0	203
1.5	305

Europa

Time (days)	θ (°)
0.0	0
1.0	101
2.0	203
3.0	305

Ganymedes

Time (days)	θ (°)
0.0	0
2.0	101
4.0	203
6.0	305

a) Plot the angular position θ as a function of time t for each moon. Determine the angular velocity $\frac{\Delta\theta}{\Delta t}$ for each moon, as well as the lowest and highest possible values given the measurement uncertainties.

b) Determine the orbital period T for each moon, along with the lowest and highest possible values.

c) The distance from Jupiter to Io is measured to be $a_{\mathrm{Io}} = 4.22 \cdot 10^5$ km. Determine the orbital radii of Europa and Ganymede, as well as their lowest and highest possible values.

d) Determine Jupiter's mass $M_{♃}$, including the lowest and highest possible values based on the uncertainties above.

10 Vector's Vector Lazor (10p)

The evil villain Vector Humlebo plans to build a deadly laser with a constant view of Earth. To avoid having to adjust its orbit, he wants to place it at a point where it naturally follows Earth's orbit around the Sun.

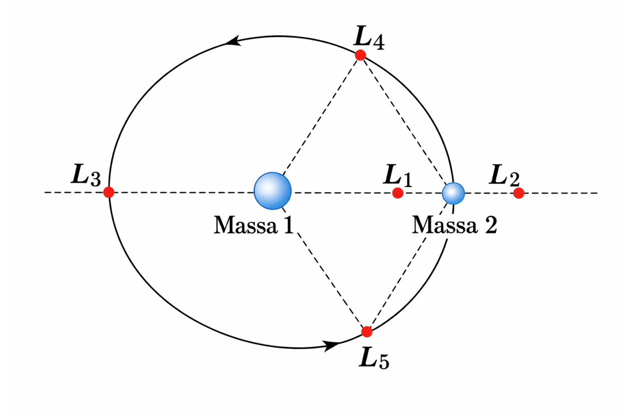
The points L_1 and L_2 are positions in the Sun–Earth system where a satellite can have the same orbital period around the Sun as Earth. These are called Lagrange points.

Consider the laser as a satellite of negligible mass located along the line passing through the Sun and the Earth.

Let the Sun's mass be M, Earth's mass be m, the distance between the Sun and Earth be R, and the system's angular velocity be ω.

a) Show that the system's angular velocity satisfies

$$\omega^2 = \frac{GM}{R^3}.$$



Figur 4: Lagrange points — L_1 and L_2, as well as the others

Assume in parts b) and c) that $x \ll R$, and use when needed the approximation

$$\frac{1}{(R \pm x)^2} \approx \frac{1}{R^2}\left(1 \mp \frac{2x}{R}\right).$$

b) Consider the point L_1, located between Earth and the Sun. Let the distance between Earth and the satellite be x, where $x \ll R$.

First determine the total gravitational acceleration on the satellite from the Sun and Earth. Then set up the condition for the satellite to rotate with the same angular velocity as Earth, and show that

$$x \approx R\left(\frac{m}{3M}\right)^{1/3}.$$

c) Now consider the point L_2, located on the opposite side of Earth. Show that the same result from part b) also applies in this case.

Use the following approximation in parts of b) och c):

$$\frac{1}{(R \pm x)^2} \approx \frac{1}{R^2}\left(1 \mp \frac{2x}{R}\right).$$

Given Solar System Data, Values and Formulae

Celestial Body	Diameter (km)	Distance from the Sun (10^6km)	Mass (kg)
Sun	$1{,}393 \cdot 10^6$	—	$1{,}989 \cdot 10^{30}$
Mercury	4879,4	57,9	$3{,}301 \cdot 10^{23}$
Venus	12104	108,2	$4{,}868 \cdot 10^{24}$
Earth	12756	149,597870	$5{,}972 \cdot 10^{24}$
Mars	6779	227,9	$6{,}417 \cdot 10^{23}$
Jupiter	142800	778,3	$1{,}898 \cdot 10^{27}$
Saturn	120660	1427,0	$5{,}681 \cdot 10^{26}$
Uranus	51118	2871,0	$8{,}681 \cdot 10^{25}$
Neptune	49528	4497,1	$1{,}024 \cdot 10^{26}$
Pluto	2376,6	5906,4	$1{,}309 \cdot 10^{22}$

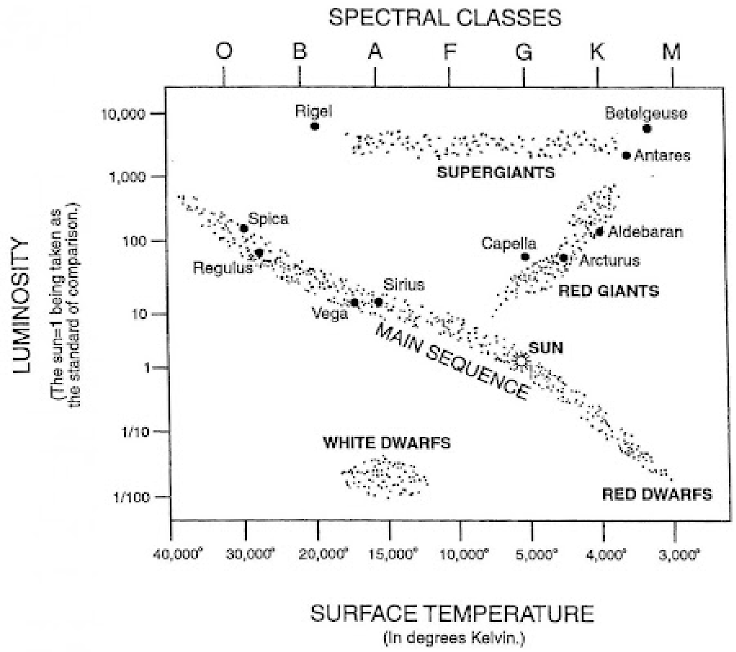
Tabell 1: Basic data of the Solar System.

Name	Value	Unit
Newton's gravitational constant (G)	$6{,}67408 \cdot 10^{-11}$	$\mathrm{N\,m^2\,kg^{-2}}$
Hubble constant (H_0)	70	$\mathrm{km\,s^{-1}\,Mpc^{-1}}$
Solar constant (G_{SC})	1360	$\mathrm{W\,m^{-2}}$
Solar luminosity ($L_\odot$)	$3{,}826 \cdot 10^{26}$	W
Solar surface temperature ($T_\odot$)	5777	K
Stefan–Boltzmann constant (σ)	$5{,}67 \cdot 10^{-8}$	$\mathrm{W\,m^{-2}\,K^{-4}}$
Speed of light in vacuum (c)	299792458	$\mathrm{m\,s^{-1}}$
Light year (ly)	$9{,}461 \cdot 10^{12}$	km
Parsec (pc)	3,262	light years (ly)
Astronomical Unit (AU)	$150 \cdot 10^6$	km
Electronvolt (eV)	$1{,}60217663 \cdot 10^{-19}$	J
Sidereal day	23,9344696	h
Julian year	365,25	days (24h)
Apparent magnitude of the Sun ($m_\odot$)	$-26{,}74$	mag
Absolute magnitude of the Sun ($M_\odot$)	4,83	mag
Peak M_V for Type Ia supernova	$-19{,}3$	mag

Tabell 2: Physical constants.

Name	Formula
Gravitational acceleration	$g = \frac{GM}{r^2}$
Gravitational force on a planet	$F_g = mg$
Density–mass relation	$M = \rho \cdot V$
Centripetal acceleration	$F_c = \frac{mv^2}{r}$
Newton's law of gravitation	$F_g = G\frac{m_1 m_2}{r^2}$
Kepler's third law	$T^2 = \frac{4\pi^2}{GM}a^3$
Kepler's third law (in Earth units)	$T^2 = \frac{a^3}{M}$
Eccentricity	$e = \frac{c}{a} = \frac{r_a - r_p}{r_a + r_p}$
Semi-major axis	$a = \frac{r_a + r_p}{2}$
Luminosity and flux	$F = \frac{L}{4\pi r^2}$
Magnitude and flux	$m_1 - m_2 = -2{,}5\log(\frac{F_1}{F_2})$
Distance modulus	$m - M = 5\log(\frac{d}{10})$
Wavelength–frequency relation	$\lambda f = c$
Lens equation	$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$
Rayleigh criterion	$\Theta = 1.22 \cdot \frac{\lambda}{D}$
Magnification	$\omega = \frac{f_o}{f_e}, \quad f_o = \text{objective focal length}, \; f_e = \text{eyepiece focal length}$
Field of view	$field\ of\ view = \frac{Field\ of\ view_{eyepiece}}{\omega}$
Wien's law	$\lambda_{max}T = 2{,}898\,\mathrm{mm\,K}$
Stefan–Boltzmann law	$L = 4\pi R^2 \cdot \sigma T^4$
Hubble's law	$H_0 r = v$
Doppler shift	$\frac{v}{c} = z = \frac{\Delta\lambda}{\lambda}$
Parallax	$d = \frac{1}{p}$
Tangential velocity	$v_t = 4{,}74\mu d$
Upper culmination	$h_{max} = 90^\circ - \varphi + \delta$
Lower culmination	$h_{min} = \delta + \varphi - 90^\circ$

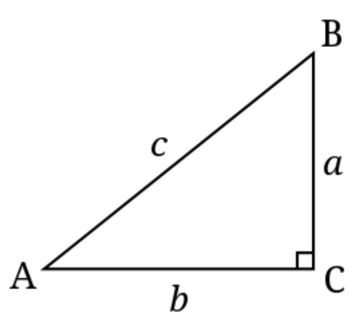
Tabell 3: Physical formulae



Figur 5: A Hertzsprung–Russell diagram

Name	Formula
Sinus	$\sin A = \frac{a}{c}$
Cosine	$\cos A = \frac{b}{c}$
Tangent	$\tan A = \frac{a}{b}$
Pythagorean theorem	$c^2 = a^2 + b^2$
Common logarithm	$10^{\log_{10} a} = \log_{10} 10^a = a$
Logarithm multiplication	$\log a \cdot b = \log a + \log b$
Logarithm division	$\log \frac{a}{b} = \log a - \log b$
Logarithm powers	$x \log a = \log a^x$

Tabell 4: Mathematical formulae



Figur 6: Right triangle for the definition of trigonometric formulae