International Astronomy and Astrophysics Competition

Pre-Final Round 2019

Important: Read all the information on this page carefully!

General Information

- We recommend to print out this problem sheet. Use another paper to draft the solutions to the problems and write your final solution (with steps) on the provided space below the problems.
- You may use extra paper if necessary, however, the space under the problems is usually enough.
- Typing the solution on a computer is allowed but not recommended (no extra points).
- The 10 problems are separated into three categories: 4x basic problems (A; four points), 4x advanced problems (B; six points), 2x research problems (C; ten points). The research problems require you to read a short scientific article to answer the questions. There is a link to the PDF article.
- You receive points for the correct solution **and** for the performed steps. Example: You will not get all points for a correct value if the calculations are missing.
- Make sure to **clearly** mark your final solution values (e.g. underlining, red color, box).
- You can reach up to 60 points in total. You qualify for the final round if you reach at least 25 points (junior, under 18 years) or 35 points (youth, over 18 years).
- It is not allowed to work in groups on the problems. Help from teachers, friends, family, or the internet is prohibited. Cheating will result in disqualification! (Textbooks and calculators are allowed.)

Uploading Your Solution

- Please upload a file/pictures of (this sheet with) your written solutions: https://iaac.space/status
- Only upload **one single PDF file!** If you have multiple pictures, please compress them into one single file. Do not upload your pictures in a different format (e.g, no Word and Zip files).
- The deadline for uploading your solution is **Sunday 12. May 2019, 23:59 UTC+0**.
- The results of the pre-final round will be announced on Monday 20. May 2019.

Good luck!

Problem A.1 : Journey to Proxima Centauri (4 Points)

The diameter of the Sun is 1.39 million kilometres and the Earth is 8.3 light minutes far away. Proxima Centauri is the nearest star - it has a distance of 4.24 light years to our Sun.

(a) How long does it take to travel to Proxima Centauri with
  (i) an airplane (920 km/h) or
  (ii) with the *Voyager 1* space probe (17 km/s).

(b) Let the Sun have the size of a tennis ball (diameter: 6.7 cm): How far away is the Earth and how far away is Proxima Centauri on this scale?

Problem A.2 : Orbit of the Solar System (4 Points)

The Milky Way has a diameter of about 150,000 light years. Our solar system is located 27,000 light years from the center of the Milky Way and orbits the center with a speed of 220 km/s.

(a) How long does it take for the solar system to circle the center of the Milky Way?
(b) The earth has formed about 4.5 billion years ago. How often has the earth circled the center?

Problem A.3 : Distance to Arcturus (4 Points)

The stellar parallax of the star Arcturus in the constellation Boötes was measures with $0.09''$.

(a) Calculate the distance (in parsec) between Arcturus and the Earth.
(b) How long does it take to send a light message from Earth to Arcturus?

Problem A.4 : From Earth to Mars (4 Points)

For a special mission to Mars you need to know the smallest distance between Earth and Mars. However, you have lost your astronomy book and you could only find these values:

Distance Earth to Sun: 149.6 million km
Orbital period Earth: 1.00 years
Orbital period Mars: 1.88 years

By using these values and assuming that Mars and Earth move an circular orbits, calculate the smallest possible distance between Earth and Mars.

Problem B.1 : New Star (6 Points)

You have discovered a new star in the Milky Way: Your new star is red and has $3/5$ the temperature of our Sun. The new star emits a total power that is 100,000 times greater than the power emitted by our Sun.

(a) Determine the spectral type (i.e. spectral classification) of the new star.
(b) How many times bigger is the radius of the new star compared to the radius of our Sun?

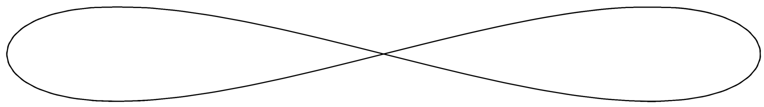
Problem B.2 : Moon Satellite (6 Points)

The Moon has a mass of $M = 7.3 \cdot 10^{22}\ kg$, a radius of $R = 1.7 \cdot 10^{6}\ m$ and a rotation period of $T = 27.3$ days. Scientists are planning to place a satellite around the Moon that always remains above the same position (geostationary).

(a) Calculate the distance from the Moon's surface to this satellite.
(b) Explain if such a Moon satellite is possible in reality.

Problem B.3 : Binary Star System (6 Points)

You are the captain of a spaceship that is circling through a binary star system. Due to the gravitational forces and the rocket engines, the orbit of your spaceship looks like that:



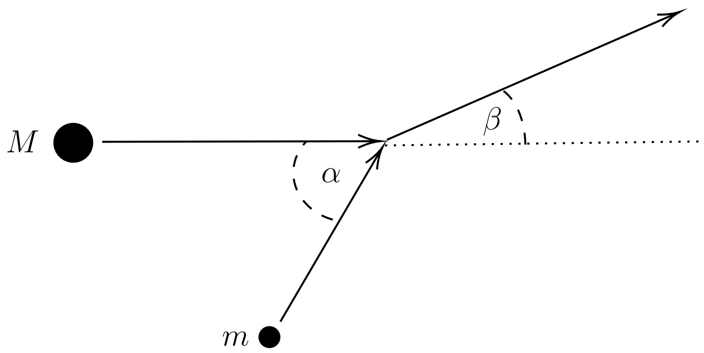
The position of your spaceship (in AU) at the time t (in days) is given by:

$$x = 5\sin(t) \qquad y = \sin(2t) \qquad z = 0$$

(a) How long does it take your spaceship to circle the orbit once?
(b) Find an equation that calculates the velocity $v(t)$ of your spaceship at a given time t.
(c) The two stars are positioned at the points $(4, 0, 0)$ and $(-4, 0, 0)$: What is the distance of your spaceship to the stars at the time $t = \frac{\pi}{2}$?

Problem B.4 : Asteroid Collision (6 Points)

A warning system has calculated that two asteroids will collide not far from Earth any time soon. The smaller asteroid has the mass m and moves with the velocity v_m. The bigger asteroid has the mass $M = 3m$ and the velocity of $v_M = \frac{1}{2} v_m$. They collide at an angle of $\alpha = 60°$ and turn into a single heavy asteroid (inelastic collision):



(a) Calculate the velocity of the single object after the collision.
(b) Determine the angle β after the collision.

Problem C.1 : The Sunburst Arc (10 Points)

This problem requires you to read following recently published scientific article:

The Sunburst Arc: Direct Lyman α escape observed in the brightest known lensed galaxy.
T.E. Rivera-Thorsen, H. Dahle, M. Gronke, M. Bayliss, J.R. Rigby, R. Simcoe, R. Bordoloi, M. Turner, and G. Furesz, Astronomy & Astrophysics 608, (2017). Link: https://www.aanda.org/articles/aa/pdf/2017/12/aa32173-17.pdf

Answer following questions related to this article:

(a) Why is it difficulty for *LyC radiation* to escape galaxies with high star formation rates?

(b) What is the difference between the *density-bounded medium* and the *picket fence model*?

(c) Explain the spectral shape of the *perforated shell model* (see article: figure 1, right box).

(d) What is the *Sunburst Arc* and how was it discovered?

(e) When did the scientist observe the object and which instruments did they use?

(f) What is the redshift of the *Sunburst Arc* and how was it determined from the data?

(g) Explain the difference between the right and the left diagram in figure 4 (see article).

Problem C.2 : Dark Matter (10 Points)

This problem requires you to read following recently published scientific article:

Probing Dark Matter Using Precision Measurements of Stellar Accelerations.

A. Ravi, N. Langellier, D.F. Phillips, M. Buschmann, B.R. Safdi, R.L. Walsworth,
arXiv:1812.07578, (2018). Link: https://arxiv.org/pdf/1812.07578.pdf

Answer following questions related to this article:

(a) What are the current methods to determine the dark matter density / radial velocity and what are the disadvantages of these methods?

(b) Explain the new method for measuring dark matter density that is proposed in the article.

(c) Let $a_r(r)$ be the dark matter contribution to the acceleration: Show that the dark matter density is given by $\rho_{DM} \approx \frac{1}{4\pi G}\left(2(A-B)^2 - \frac{\partial a_r}{\partial r}\right)$ with Oort constants $2(A-B)^2 = 2GM(r)/r^3$.

(d) How much does the velocity of the stars change during the lifetime of a human (80 years)?

(e) What is important for measuring stellar accelerations and which instruments can be used?

(f) Explain the curves of the four diagrams in figure 2 (see article).