UiO : Institutt for teoretisk astrofysikk
Universitetet i Oslo

Rosseland Centre for Solar Physics

International Olympiad on Astronomy and Astrophysics

Final Round 2021/2022

Date: Friday April 1st 2022 - week 13

Allowed aids: Calculator, pencil/pen, 1 answer sheet, 2 blank sheets. Physical constants and formulas are given below.

Time: 90 minutes

The exam is composed by two sections for a total of 15 multiple choice questions and 2 open questions.

Section 1 – multiple choice problem set. There are four possible answers for each problem - A, B, C og D. Use the answer sheet to mark the letter corresponding to your chosen answer. There is only one single correct answer for each problem and all problems yield the same number of points. Zero points are given for a problem if more than one answer is marked. Wrong answers do not yield negative points.

Section 2 – open questions. There are two open questions, each gives 3 points. Write your name and date on the sheet with your final answer. You shall write your answer in English.

Good luck!

Constants and formulas:

- Speed of light = 299792458 m/s
- 1 parsec (pc) ≈ 3.26 light years
- Newton's law of gravity: $F_G = GmM/r^2$, $G \approx 6.67 \cdot 10^{-11}$ m^3/kg/s^2
- Wien law: $\lambda_{max} = b/T$, $b \approx 2.9 \cdot 10^6$ nm·K
- Stefan-Boltzmann's law: $F = \sigma T^4$, $\sigma \approx 5.67 \cdot 10^{-8}$ W/m^2/K^4
- Apparent magnitude: $m = -2.5\log(F/F_0)$
- Hubble's law: $v = H_0 d$, $H_0 \approx 73$ km/s/Mpc
- Doppler formula: $v/c = (\lambda - \lambda_0)/\lambda_0$
- The Rayleigh criterion: = $1.22 \cdot \lambda/D$ rad

Section 1. Multiple choice questions. Each correct question gives 1 point.

1. Read the following statements and choose the correct option:

P. Eclipses are not distributed evenly throughout the year, but happens only in certain months of a given year.
Q. Orbit of the Moon (around the Earth) makes an angle of roughly 5 degrees to the orbit of Earth (around Sun).

a) Statement 'P' is correct but 'Q' is incorrect
b) Statement 'P' is incorrect but 'Q' is correct
c) Both statements are correct and 'Q' is the correct reason for 'P'
d) Both statements are correct and 'Q' is not the reason for 'P'

2. An astronaut throws a ball out from a rocket far into space. The ball just grazes the upper edge of the atmosphere during its trajectory. It will…

a) Go around the Earth.
b) Crash on the Moon.
c) Get lost into deep space.
d) Reach the Olympiad venue again.

3. What is the spectral type of a star with a luminosity of 5.86×10^{26} W and radius of 8.51×10^{8} m?

a) A
b) F
c) G
d) K

4. Every object exerts gravitational force on every other object - The force exerted by an object is higher if its mass is higher. Consider 2 magnets - a bigger magnet P and a smaller one Q. Which of the following will be true?

a) Magnet P will exert a greater magnetic force than Q
b) The magnetic forces exerted by P and Q will be the same
c) Magnet Q will exert a greater magnetic force than P
d) We cannot tell from the sizes, as gravity and magnetism are unrelated

5. Order chronologically the following phases of the Sun's evolution from first to last.

1. Helium flash
2. White dwarf
3. Red giant branch
4. Asymptotic giant branch
5. End of hydrogen fusion in the core

a) 5, 4, 1, 3, 2
b) 5, 3, 1, 4, 2
c) 1, 5, 3, 4, 2
d) 5, 2, 4, 1, 3

6. The distance between two objects with equal mass is doubled. By how much does the gravitational force between the objects decrease?

a) $1/\sqrt{2}$
b) 1/2
c) 1/4
d) 1/8

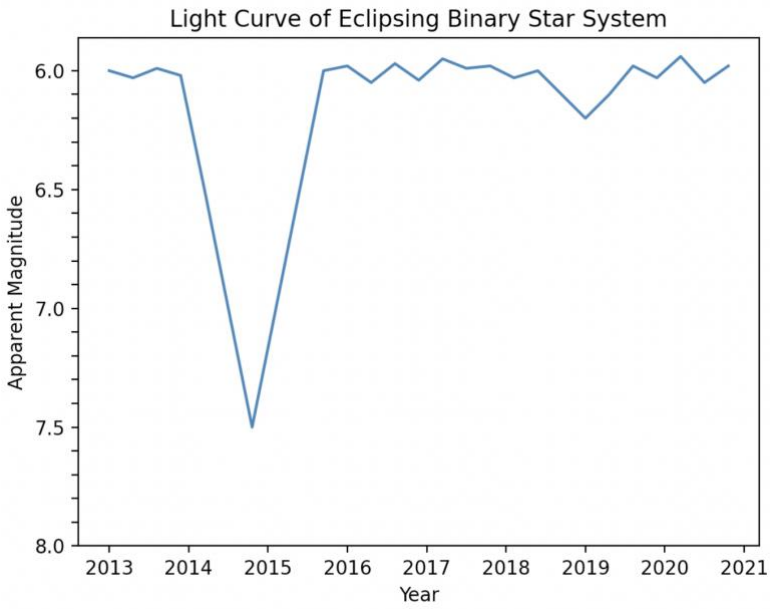
7. In 2025, the Parker Solar Probe will pass just 6.9 x 10^6 km from the Sun, becoming the closest man-made object to the Sun in history. It will make five orbits, passing close to the Sun once every 89 days, before the planned end of the mission in 2026. How fast will the Parker Solar Probe be traveling at its closest approach to the Sun?

a) 38 km/s
b) 48 km/s
c) 139 km/s
d) 190 km/s

8. On the main sequence, stars obtain their energy

a) from gravitational contraction.
b) by converting hydrogen to helium.
c) by converting helium to carbon, nitrogen, and oxygen.
d) from nuclear fission.

9. An astronomer observes an eclipsing binary star system from Earth, and she plots the light curve on the right. Suppose that both stars have circular orbits and the distance between the stars is 14.8 AU. What is approximately the total mass of the binary star system in terms of solar masses $M_{\odot}$?



a) 2.3 $M_{\odot}$
b) 5.7 $M_{\odot}$
c) 23 $M_{\odot}$
d) 46 $M_{\odot}$

10. Imagine that a total solar eclipse happens on the Earth today. What is the phase of the Moon on this day?

a) New Moon
b) Waxing crescent
c) Waning gibbous
d) Full moon

11. The Vernal equinox is the intersection point between ...

a) the Earth's rotational axis and the horizon.
b) the celestial equator and the ecliptic.
c) the celestial equator and the horizon.
d) the Earth's rotational axis and the ecliptic.

12. An exoplanet was observed during its transit across the surface of a bright star. Estimate the variation of the apparent magnitude (Δm) of the star caused by exoplanet's transit. During the transit, assume an Earth-based astronomer observes that the area covered by the exoplanet on the projected surface of the star represents η = 2% of the star's projected surface.

a) -4.247
b) 0.003
c) -0.679
d) 0.022

13. A comet's orbit has the following characteristics: eccentricity e = 0.995; aphelion distance $r_a = 5 \times 10^4$ AU. Assume we know the mass of the Sun $M_\odot = 1.98 \times 10^{30}$ kg, and gravitational constant $G = 6.67 \times 10^{-11}\text{Nm}^2\text{kg}^{-2}$. Determine the velocity of the comet at its aphelion.

a) 9.19 m/s
b) 20.57 m/s
c) 187.91 m/s
d) 63.38 m/s

14. The diameter of the lens' aperture of your telescope is 5 m and you observe at a wavelength of 1000 nm. What is the resolution of this telescope?

a) 0.08 arcsec
b) 2 degrees
c) 0.025 arcsec
d) 0.05 arcsec

15. An astronomer took the picture below while observing the night sky. What is the latitude of the place where the astronomer took the picture?

a) 2° N
b) 20° S
c) 20° N
d) 75° N

Section 2. Open questions. Each correct question gives 3 points.

1. Mars orbits the Sun at an average distance of 2.28×10^{11} m and has a radius of 3.39×10^{6} m. The Sun has a luminosity of 3.828×10^{26} W. How much solar energy falls on the surface of Mars each second? Ignore any effects of Mars' thin atmosphere.

2. Suppose that at some time in the very recent past all the hydrogen and helium in the universe had been instantly fused into iron in stars, and the released energy thermalized into black body radiation.
Consider: baryon density $\rho_b = 4.2 \times 10^{-31}\text{gcm}^3$, about 75% hydrogen (=1 baryon) by mass and 25% helium (=4 baryons) by mass.
Note that the binding energy per nucleon of $^{56}_{26}Fe$ is 8.8 MeV and that of $^{4}_{2}He$ is 7.1 MeV.)

a) What is the current temperature of this black body radiation? (2 points)
b) Determine what wavelength the blackbody spectrum would peak at. What region of the electromagnetic spectrum would this be in? (1 point)