National Astronomy Olympiad

2013-2014

Duration: 2 hours 30 minutes

Maximum Points: 66 (Multiple Choice: 32 points, Long Questions: 34 points)

This test is designed to be taken with an answer sheet and scantron sheet on which the student records his or her responses. All answers are to be marked on these sheets, not written in the booklet. Anything written in the test booklet will not be scored. Students must begin each Long Answer on a new sheet, clearly indicating the question number. Each student should be provided with an answer sheet and scratch paper, both of which must be turned in with the test booklet at the end of the examination.

The full examination consists of 16 multiple-choice questions and 3 Long Answer questions representing a fairly wide range of difficulty. Students should be permitted to use scientific calculators. A table of physical constants other useful information are provided as an attached booklet.

Do not discuss this examination with anyone after its completion. Your results will be emailed to you by March 20th.

I hereby affirm that all work on this exam is mine, and that I took this test under a proctor's supervision, with no outside aids beyond the materials provided and allowed. Furthermore, I also affirm to not discuss the test with others or provide any sort of aid to other examiners through the course of the examination. I understand that failure to do so may result in your disqualification from the exam.

Signature: _____ Date:_____

Section A: Multiple Choice [32 points]

1. Which of the following constellations are visible during the summer?
    A. Delphinus
    B. Taurus
    C. Monoceros
    D. Eridanus

2. Which stars make up the Winter Triangle asterism?
    A. Regulus, Spica, Arcturus
    B. Sirius, Procyon, Betelgeuse
    C. Vega, Altair, Deneb
    D. Alpheratz, Algenib, Markab

3. The moon is at its upper culmination at 8pm, mean solar time. Estimate the phase of the moon.
    A. Waning Gibbous
    B. Waning Crescent
    C. Waxing Gibbous
    D. Waxing Crescent

4. Arrange the following stages of the life cycle of a star of one solar mass in chronological order - Red-giant branch, Planetary nebula, White dwarf, Main sequence star, Helium Flash.
    A. Main sequence star, Red-giant branch, Helium Flash, Planetary nebula, White dwarf
    B. Main sequence star, Helium Flash, Red-giant branch, Planetary nebula, White dwarf
    C. Main sequence star, Red-giant branch, Helium Flash, White dwarf, Planetary nebula
    D. Main sequence star, Helium Flash, Red-giant branch, White dwarf, Planetary nebula

5. How are the rings of Saturn thought to be formed?
    A. They coalesced during the formation of the Solar System
    B. They were ejected from the surface of Saturn by a massive meteor impact.
    C. They are the disintegrated remains of some of Saturn's moons and captured meteorites
    D. They were gravitationally captured from the interstellar medium

6. The James Webb Space Telescope is to be sent to the second Lagrange point of the Earth-Sun system. What is the significance of doing so?
    A. The telescope would require little expenditure of energy to maintain its orbit
    B. The Earth would shield the telescope from the intense solar radiation
    C. The Moon would shield the telescope from the intense solar radiation
    D. It allows for ground control to communicate easily with the telescope

7. Which of the following is not a possible method of detecting exoplanets?
    A. To observe the wobbling of the parent star due to the gravitational influence of the planet
    B. To observe the doppler shift of light emitted by the parent star due to the gravitational influence of the planet
    C. To observe the periodic dips in the brightness of the parent star due to planetary transits
    D. All of the above are possible methods for detecting exoplanets

8. An 8 inch Dobsonian telescope with a focal ratio of f/6 is used with a 12mm Plossel eyepiece. Calculate the magnifying power of the telescope. *(1 inch = 25.4mm)*
    A. 30x
    B. 50x
    C. 100x
    D. 200x

9. Approximately how much higher is the limiting magnitude of a telescope than that of the human eye? Assume that the telescope has an aperture of 200mm and the diameter of the human iris is 5mm. *(A magnitude difference of 5 corresponds to a 100-fold difference in luminosity).*
    A. 6.0
    B. 7.0
    C. 8.0
    D. 9.0

10. What is the advantage of an Equatorial telescope mount as compared to an Alt-az mount?
    A. Reduced vibrations and provides a more stable viewing platform
    B. Convenience of tracking the diurnal motion of the stars
    C. It can be made more compact than an Alt-az mount
    D. It is less complex than the Alt-az mount

11. Alberio (β Cygni) is a double star system in the constellation Cygnus. The magnitudes of the component stars Alberio A & Alberio B are given by 3.18 and 5.82 respectively. Find the apparent magnitude of Alberio.
    A. 2.96
    B. 3.09
    C. 3.49
    D. 4.75

12. Which of the following stars is circumpolar in Romania (44°25'N 26°06'E)? *(Circum-polar stars are stars that never set).*
    A. ζ Herculis (16h41m/+31°36')
    B. β Böotis (15h01m/+40°23')
    C. θ Aurigae (5h59m/+37°12')
    D. γ Draconis (17h56m/+51°26')

13. Haley's comet last appeared in the night sky in 1986. The Perihelion and Aphelion of its orbit are given by 0.586AU & 35.1AU respectively. Predict when it will next return.
    A. 2036
    B. 2052
    C. 2061
    D. 2096

14. What would be the maximum speed of a meteor on a parabolic orbit around the sun, whose point of closest approach is 1AU?
    A. 42.1 km/s
    B. 58.4 km/s
    C. 77.1 km/s
    D. 92.8 km/s

15. Estimate the lifespan of the Sun. (Mass of H : 1.00794u; Mass of He : 4.002602u)

    A. 8.5 Billion Years
    B. 9.6 Billion Years
    C. 10.2 Billion Years
    D. 10.7 Billion Years

16. Calculate the length of the shortest day that can be experienced in Romania (44°25'N 26°06'E). *(Earth's axial tilt is 23.4)*

    A. 8h 12m
    B. 8h 39m
    C. 9h 04m
    D. 9h 25m

Section B: Long Questions [34 points]

1. One way to send a spacecraft to mars would be to employ an elliptical orbit with Earth at its perihelion and Mars at its aphelion. You may assume that Mars revolves around the Sun in a circular orbit of radius 1.52 AU.
   (a) How long does it take for the spacecraft to reach Mars? [4]
   (b) Assuming that the spacecraft is launched in the prograde direction, what elongation angle of mars should it be launched at to ensure that the spaceship reaches its destination? *(A prograde direction is in the same direction as that of the orbits of the planets. The elongation angle of mars is the angle between the Sun and mars as seen from the earth.)* [8]

2. Circumpolar stars are stars that never set below the horizon. Consider such a star with declination δ, as seen by a northern observer at latitude Φ.
   (a) Draw a figure that illustrates the motion of such a star in the sky. Label all relevant angles. [3]
   (b) Find the condition δ and Φ must fulfill for the star to be circumpolar. [3]
   (c) Write an expression (in terms of δ and Φ) for the maximum azimuth of a circumpolar star that cannot reach 180 degrees. *(The azimuth of a star is its angle from north)* [6]

3. The critical density of the Universe is the density at which the gravitational attraction of matter within the universe is balanced with its expansion in such a way that neither will ultimately prevail. If the density of the universe were lower than this critical density, expansion will continue indefinitely. On the other hand, if the density of the universe were any higher, it would re-collapse upon itself.
   (a) The critical density of the universe is given by:

$$\rho_c = \frac{3{H_0}^2}{8\pi G}$$

   It is possible to arrive at this result through classical means. By modeling the universe as of having infinite extent and uniform density, expanding linearly with velocity $v = H_0 x$ derive the above expression. [6]
   (b) The density of ordinary (baryonic) matter in the universe is determined to be about 3.8×10^{-28} kg m^{-3}. Hence, provide a justification for the existence of dark matter. *(Latest estimates of the Hubble constant suggest a value of 2.20×10^{-18} s^{-1})* [4]