



International Olympiad on Astronomy and Astrophysics

Norwegian problem set for the first round

2021/2022 school year

Date: Any date during week 47-48 (22 November– 3 December 2021)

Allowed aids: Calculator, pencil/pen and physical constants and formulas given below

Time: 90 minutes

This is a multiple choice problem set. There are four possible answers for each problem - A, B, C og D. Use the answer sheet at the end of the problem set to mark the letter corresponding to your chosen answer. There is only a 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.

The problem set has 7 pages, and there are 26 problems.

Good luck!

Constants and formulas:

- Speed of light = 299792458 m/s
- 1 parsec (pc) \approx 3.26 light years
- Newton's law of gravity: $F_G = GmM/r^2$, $G \approx 6.67 \cdot 10^{-11} \text{ m}^3/\text{kg/s}^2$
- Wien law: $\lambda_{max} = b/T$, $b \approx 2.9 \cdot 10^6 \text{ nm}\cdot\text{K}$
- Stefan-Boltzmann's law: $F = \sigma T^4$, $\sigma \approx 5.67 \cdot 10^{-8} \text{ W/m}^2/\text{K}^4$

- Apparent magnitude: $m = -2.5 \log (F/F_0)$
- Hubble's law: $v = H_0 d$, $H_0 \approx 73 \text{ km/s/Mpc}$
- Doppler formula: $v/c = (\lambda - \lambda_0)/\lambda_0$
- The Rayleigh criterion: $= 1.22 \cdot \lambda/D \text{ rad}$

1. The Hulse-Taylor binary system consists of a pulsar and a neutron star, and has an orbital period of 7.75 hours. The orbital period is observed to decrease by 70 nanoseconds per orbit. What is the cause?
 - a) Systematic errors caused by the instrumentation.
 - b) The time is observed as shorter due to relativistic time dilation.
 - c) The binary system loses energy by emitting gravitational waves.
 - d) There is an unobserved third perturbing body in the system.

2. What is the local sidereal time at the moment when the point of vernal equinox disappears below the horizon ?
 - a) 0 hours
 - b) 6 hours
 - c) 12 hours
 - d) This cannot be determined from the available information

3. Two stars, A and B, of equal physical size have apparent magnitudes of -4.5 and 1.5, and absolute magnitudes of 1.5 and -4.5, respectively. We can conclude that:
 - a) A is much warmer and closer to the Earth than B
 - b) B is much warmer and closer to the Earth than A
 - c) A is much warmer than B and B is much closer to the Earth than A
 - d) B is much warmer than A and A is much closer to the Earth than B

4. The expansion of the universe makes distant objects move away from us at a velocity called the Hubble velocity. This velocity can be calculated from Hubble's law, $v = H_0 D$, where $H_0 \sim 70 \text{ km/s/Mpc}$ is the Hubble constant and D is the distance from us. What is the Hubble velocity of galaxies observed at a distance of 100 kpc from us? (Mpc = Megaparsec)
 - a) 70 km/s
 - b) 7 km/s
 - c) 700 km/s
 - d) 0.7 km/s



5. The figure shows a telescope on an equatorial mount. What type of telescope is it, and what is measured by the setting circles A and B ?
- a) Reflector. A measures hour angle. B measures declination.
 - b) Refractor. A measures hour angle. B measures declination.
 - c) Refractor. A measures declination. B measures hour angle.
 - d) Reflector. A measures declination. B measures hour angle.
6. The thermal pressure of an (ideal) gas depends on
- a) Density only
 - b) Pressure only
 - c) Both density and pressure
 - d) Gravity
7. The Pole Star has a fixed position in the night sky because...
- a) the Earth has zero velocity relative to the Pole Star
 - b) the Earth lies on the rotation axis of the Pole Star
 - c) the Earth and the Pole Star both have the same velocity inside the Milky Way galaxy
 - d) None of the alternatives above
8. Uranus and Neptune both have methane clouds, but Jupiter and Saturn don't. What is the reason for this ?
- a) The rapid rotation of Jupiter and Saturn prevents the formation of methane clouds.
 - b) The stronger gravity on Jupiter and Saturn drags the methane down such that clouds cannot form.
 - c) Methane cannot condense into clouds at the higher temperatures of Jupiter and Saturn.
 - d) Jupiter and Saturn have no methane gas.
9. The main reason for the presence of volcanic activity on Io is:
- a) Io's magnetic field
 - b) Internal heat preserved from the formation of the Solar System
 - c) The eccentricity of Io's orbit
 - d) Tidal forces from Jupiter

10. How can the existence of dark matter solve the problem of galactic rotation curves?
- a) By exerting friction on the visible matter, the dark matter decreases the rotation velocity in the center of the galaxy.
 - b) The dark matter produces a mass profile which decreases slower with increasing radius, resulting in a flatter rotation curve.
 - c) Interactions between dark and visible matter establishes thermodynamic equilibrium at a quicker rate.
 - d) The dark matter obscures the light from the visible matter, causing us to underestimate the total mass content.
11. Star A has a temperature of 4000 degrees Kelvin and star B has a temperature of 40 000 K. If these stars have approximately the same radius, which of the following statements will not be true?
- a) B is more luminous than A
 - b) A emits more infrared light than ultraviolet light
 - c) B emits more ultraviolet light than infrared light
 - d) A emits more infrared light than B
12. When using equatorial coordinates the vernal equinox is used as a reference point for:
- a) Right Ascension
 - b) Azimuth
 - c) The Earth's position
 - d) Declination
13. A star which is located in the outskirts of a galaxy of radius $R = 10$ kpc moves in an orbit around the galaxy at an orbital velocity of $v = 250$ km/s. The mass of the galaxy can be approximated by which of these values?
- a) 10^{25} kg
 - b) 10^{51} kg
 - c) 10^{36} kg
 - d) 10^{41} kg
14. The spectrum of a blackbody peaks at a wavelength inversely proportional to its temperature. This is known as Wien's law and is used to estimate stellar temperatures. The Sun can be approximated as a blackbody with its peak wavelength in the visible portion of the spectrum and a surface temperature of

6000K. Given this information, estimate the peak wavelength of a human being, assuming it to be a black body.

- a) 10 nm
- b) 10 μm
- c) 10 mm
- d) 10 m

15. Which of the following has the longest wavelength?

- a) UV
- b) Visible light
- c) Radio waves
- d) X-rays

16. A space telescope with an aperture diameter of 1.5m observes light with a wavelength of 500nm. What is the angular resolution ?

- a) $8.4 \cdot 10^{-2}$ arcseconds
- b) $4.0 \cdot 10^{-2}$ arcseconds
- c) $1.95 \cdot 10^{-1}$ arcseconds
- d) 8.4 arcseconds

17. The 21cm absorption line is a tracer for what type of gas?

- a) Cold neutral atomic hydrogen
- b) Cold molecular hydrogen
- c) Warm neutral hydrogen
- d) HII regions

18. If we assume that the Hulse-Taylor binary has a circular orbit, that both components have a mass of 1.4 solar masses, and that they orbit at a distance of 3 solar radii. Which of these numbers do most closely match the loss of energy per orbit?

- a) 0 J
- b) 1×10^{30} J
- c) 1×10^{25} J
- d) 1×10^{20} J

19. On which date does the Sun reach its highest declination?

- a) December 21st
- b) September 21st
- c) June 21st
- d) March 21st

20. An interesting phenomenon in our Solar System is the capture of comets from the interstellar medium. Assume that a comet with a mass of 7.15×10^{16} kg is captured by the Solar System. The perihelion of this comet's orbit after it is captured is equal to 4.64 AU, and its velocity with respect to the Sun before being captured by the Solar System is very small. Calculate the velocity of the comet at this position.

- a) 7.1 km/s
- b) 45.9 km/s
- c) 19.6 km/s
- d) 105.4 km/s

21. Galaxies have a peculiar motion velocity with respect to each other (separate from the Hubble expansion velocity) of approximately $v \approx 100$ km/s. At what distance from us can we expect the peculiar velocity of a galaxy to be approximately the same as its Hubble velocity $v = H_0 D$?

- a) 1.5 Mpc
- b) 10 Mpc
- c) 100 kpc
- d) 10 kpc

22. Which of the following statements is wrong?

- a) According to our theories for the origin of the elements, the elements which are heavier than iron are mostly produced by supernova explosions.
- b) Stars are kept stable by hydrostatic equilibrium between pressure forces and gravity.
- c) The granulation of the Sun (the bright spots) is generated in the Sun's corona.
- d) Main sequence stars are progressively more massive at an earlier spectral class (OBAFGKM).

23. Which statement about the Universe is correct?

- a) The size of the observable universe is approximately 1000 kpc
- b) The energy budget of the present-day universe is dominated by matter
- c) The age of the universe is approximately 14 billion years
- d) The epoch during which the energy budget of the universe was dominated by radiation occurred before the epoch of inflation

24. Which of the following type of planet was first observed around a solar-type star?

- a) Earthlike planet
- b) Super-earth
- c) Hot neptune
- d) Hot jupiter

25. Which astronomical event occurs when the Earth's axis is perpendicular to a line between the Sun and the centre of the Earth?

- a) Solstice
- b) Eclipse
- c) Equinox
- d) Full moon

26. Which point marks the approximate location of the Sun in the Hertzsprung-Russell diagram? (See the figure)

- a) a
- b) b
- c) c
- d) d

