

Norwegian Olympiad on Astronomy and Astrophysics

Problem set for Round I

2025/2026 school year

Date: Any date during week 42 – 45 (13 October – 7 November 2025)

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

Time: 90 minutes.

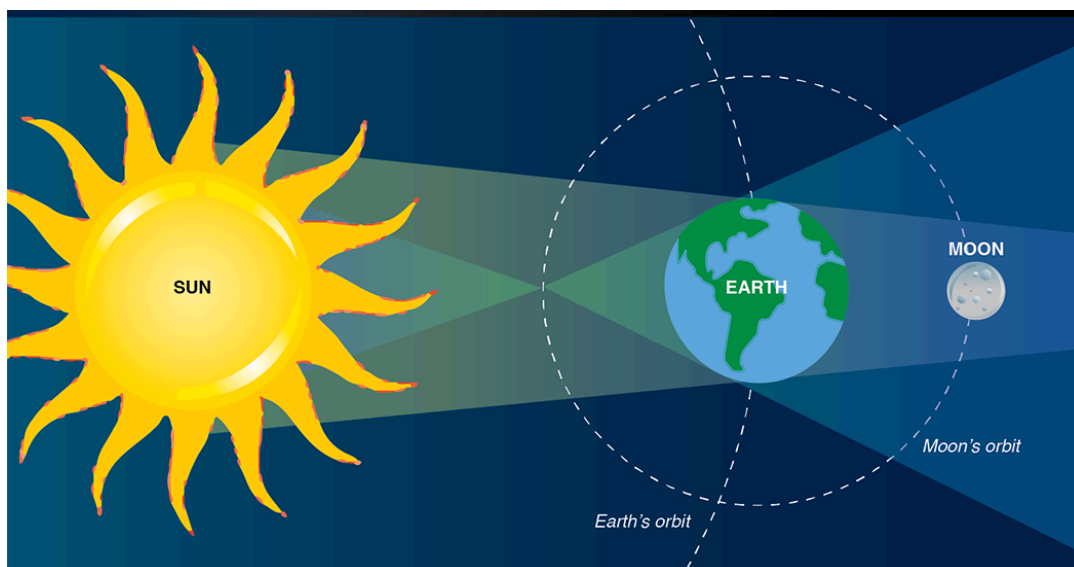
This is a multiple choice problem set. There are four possible answers for each problem - A, B, C og D. Use the answer sheet at the end of the problem set to mark the letter corresponding to your chosen answer. There is only a single correct answer for each problem and all problems yield the same number 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 12 pages, and there are 20 problems. Good luck!

Constants and formulas:

- 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: $\theta = 1.22 \cdot \lambda/D \text{ rad}$
- Speed of light = 299792458 m/s
- 1 parsec (pc) $\approx 3.26 \text{ light years}$
- 1 Astronomical Unit (AU) $\approx 1.5 \cdot 10^{11} \text{ m}$ (the average distance between the Sun and the Earth)
- 1 light year $\approx 63241.1 \text{ AU}$
- 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: $F = \sigma T^4$, $\sigma \approx 5.67 \cdot 10^{-8} \text{ W/m}^2/\text{K}^4$

- 1) As shown on the sketch below, a Full Moon happens when the Moon is behind the Earth as seen from the Sun. We also know that lunar eclipses occur when the Sun, the Earth and the Moon are in line with each other, so why isn't every Full Moon also a lunar eclipse?

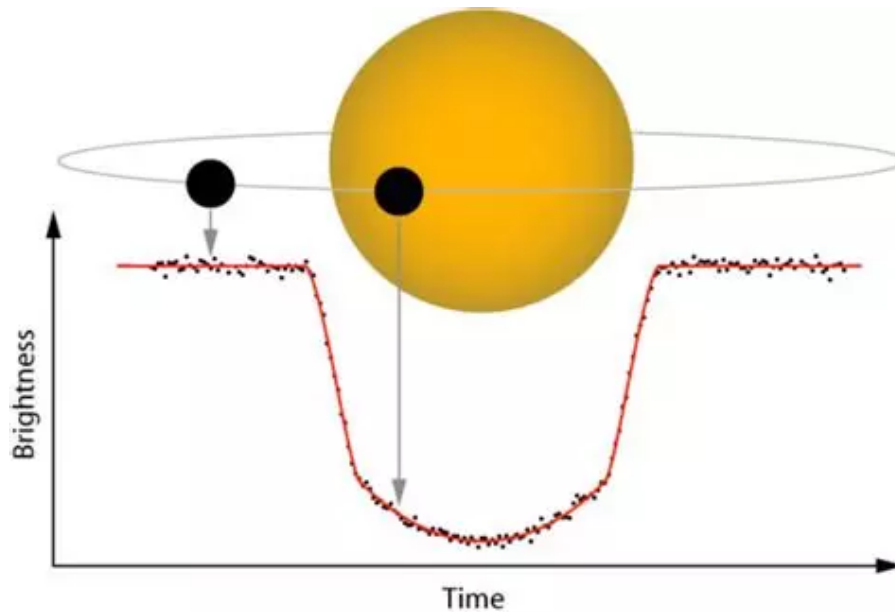


- The Moon's orbit is inclined (tilted) in relation to the Earth's orbit around the Sun, and an eclipse can only happen when Earth's shadow is cast on the Moon, which only happens when conditions align.
 - Every Full Moon is a lunar eclipse, but the characteristic red colour can only be observed when the Sun is about to set.
 - Because lunar eclipses happen at New Moon, when the Moon is between the Sun and Earth.
 - Because the distance between the Earth and the Sun changes throughout the year, so the shadow that Earth casts isn't always big enough to cover the Moon.
- 2) A total lunar eclipse, also called a "blood moon", occurred in the beginning of September 2025, but the Moon was red also a couple of days after. One possible explanation was that this is due to the Moon being low on the horizon. Is this a valid explanation and why?

- a) It isn't - the observed effect was a tidal lock when the Sun, the Moon and Earth move in synchrony in the period after an eclipse, so that it lasts longer.
 - b) It is - the light reflected off the Moon needs to travel longer through the atmosphere when the Moon is low on the horizon, and the blue light is scattered more, leading to a redder appearance.
 - c) It isn't - the reddening is a consequence of the Doppler shift in the light reflected off of the Moon; when an eclipse is over, the Moon tends to move away from the Earth, leading to a redshift.
 - d) It is - Mars is always very low on the horizon, so when the Moon is as well, the light from the Sun reflects off of Mars and gives the Moon a red tint, which is amplified by smoke from forest fires accumulated low on the horizon.

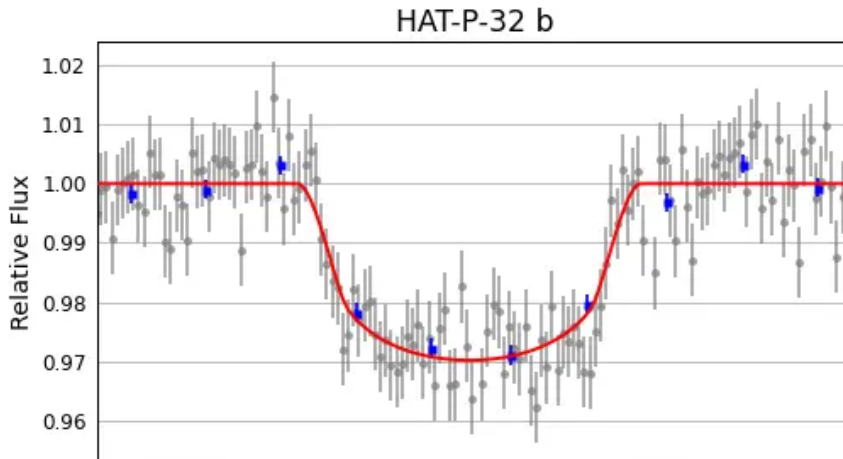
- 3) The small angle approximation is a useful trick when having to use trigonometric functions on angles significantly smaller than 1 (measured in radians). It states that for $\theta \ll 1$, you can simplify the trig functions as following: $\sin \theta \approx \tan \theta \approx \theta$ and $\cos \theta \approx 1$.
 A galaxy has a radius of 25 000 light years and is 10 million light years away from Earth. Using the small angle approximation, calculate its angular radius in arcminutes ($60 \text{ arcminutes} = 60' = 1^\circ$).
(Question made by F. Neumann, winner of Astro-OL 2023 and 2024)
 - a) 40.5'
 - b) 0.1'
 - c) 2.2''
 - d) 8.6'

- 4) Transit photometry is a way of detecting exoplanets based on finding a dip in the star's brightness when the planet passes between the observer and the star (a transit event). Which one of the following is not true about transit photometry? *(Question made by Tereza Strbkova, winner of Astro-OL 2024)*

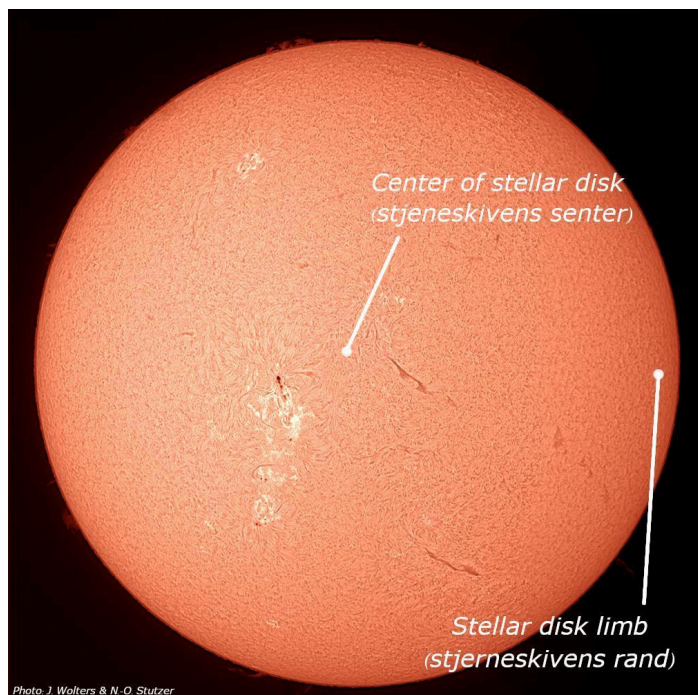


Transit photometry method for finding exoplanets. Credits: [PhysicsFeed. \(2020\)](#).

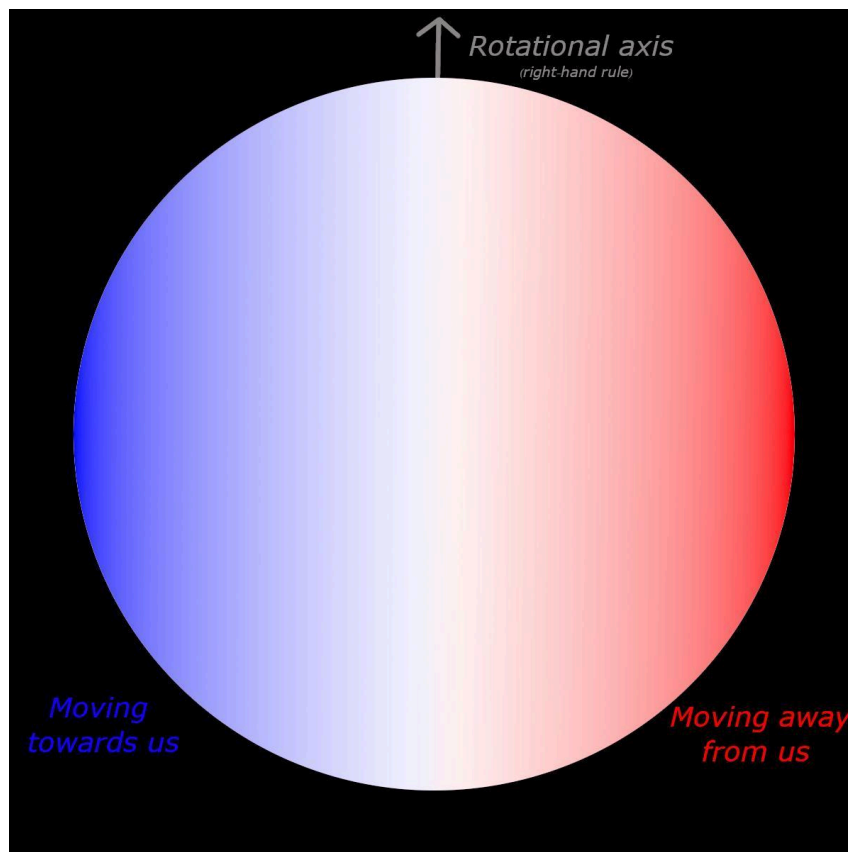
- a) Transit photometry is biased towards detecting planets with short orbital periods because one faster observes several transits at regular intervals, establishing the presence of a planet.
 - b) It helps determine the star-planet radius ratio using the transit depth.
 - c) An advantage of the method is its low rate of false positives compared to other methods, because any transiting object will lead to a brightness dip, not just planets.
 - d) Water vapor in a planet's atmosphere may be detected by comparing the star's spectrum during the transit to the spectrum otherwise.
- 5) When an exoplanet happens to move between us and its parent star, the brightness of the star will appear to dim, which is reflected as a dip in the flux curve as can be seen on the image below. We can notice that the bottom of the curve is not completely flat, but has a downwards curvature - based on this curve, what statement can we make about the star?



- a) The disk of the star is uniform in brightness
 - b) There is a disk of dust surrounding the star
 - c) The star appears darker at the limb than at its center
 - d) The star appears darker at the center than at its limb
- 6) Assuming you have a star observed at the Balmer line $H\alpha$ (H-alpha) at a wavelength of 656.28 nm. When you look at the star, it appears darker at the limb of the disk than at its center, just like in the image below. What does that tell us about the layer of the stellar atmosphere we are observing with the $H\alpha$ wavelength?



- a) The temperature is increasing outwards from the center of the star
 - b) The temperature is increasing towards the center of the star
 - c) The temperature is increasing sideways along the star's surface
 - d) There is no change in the temperature across the atmosphere
- 7) Assume you are looking at a distant star. The star is observed edge on, and the rotational axis of the star itself perpendicular to our line-of-sight. Because the star is rotating, the side of the star that is moving towards us will appear doppler shifted into the blue, while the other half of the star moving away from us will experience a redshift. Assume we observe the distant star using the $H\alpha$ emission line. What statement is true about the observed $H\alpha$ emission line of the rotating star:

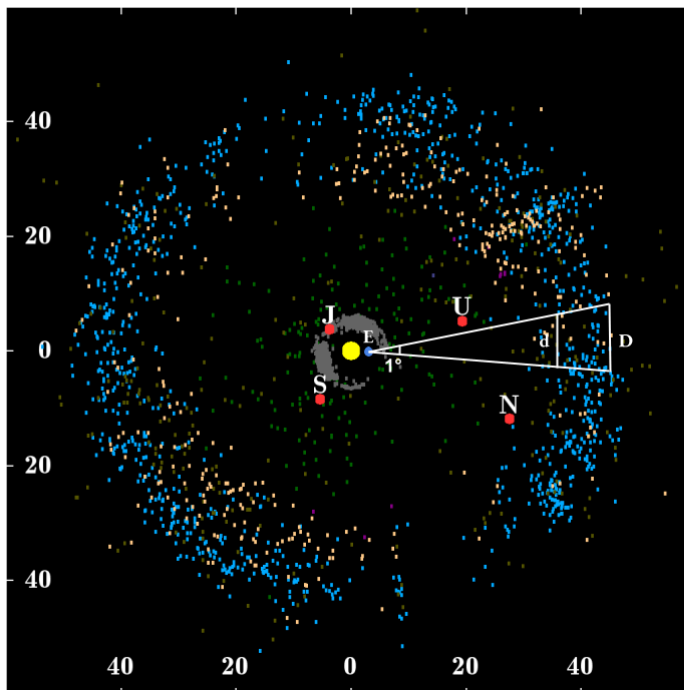


- a) The line will be infinitely narrow
- b) The line will appear narrower than in a lab measurement
- c) The line appear at a different wavelength redwards of a lab measurement
- d) The line will be broader than in a lab measurement

- 8) Hubble-Lemaitre's law states that for (low redshift galaxies) we have a simple linear relationship between the speed at which galaxies move away from us (in the Milky Way) and the distance to them: $v = H_0 d$ where v , H_0 and d are respectively the speed of the galaxy, the Hubble constant $H_0 \approx 73$ km/s/Mpc, and the distance to the galaxy. Cosmologist Marie is looking at a distant galaxy and observes that the H α emission line of hydrogen appears at 662.84 nm instead of the usual 656.28 nm measured in a lab. Using the doppler formula (see provided formulae) and Hubble-Lemaitre's law, Marie finds that the distance between her and the galaxy is approximately

- a) 1530.7 lyr
 - b) 41.6 Mpc
 - c) 107 Gpc
 - d) 3141 AU
- 9) The Kuiper belt stretches from roughly 30 to 55 AU from the Sun. You are observing Kuiper's belt from Earth with an amazing telescope, with a one degree field of view, that can clearly see Kuiper's belt. Approximating the Kuiper belt as a flat disk, what area of the Kuiper's belt can the telescope observe?

- a) 18 AU²
- b) 19 AU²
- c) 21 AU²
- d) 22 AU²



10) Knowing that the Cosmic Microwave Background radiation (CMB) has a temperature of approximately -270.42 degrees Celsius, at what wavelength is the peak of its radiation?

- a) 1.06 mm
- b) 1.06 cm
- c) 106 μm
- d) 1006 nm

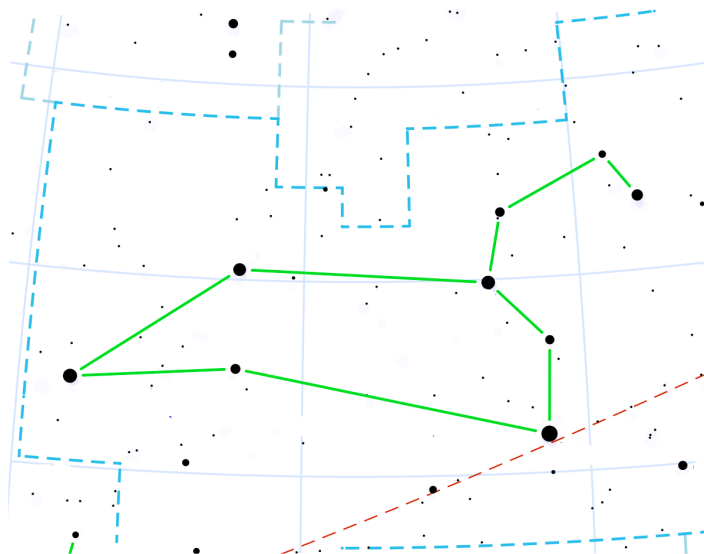
11) Escape velocity is the minimum speed needed for an object to escape a planet's gravity and never fall back. Both the kinetic energy and gravitational potential energy are zero when an object has escaped its gravitational pull. Using conservation of energy, what is the formula for escape velocity?

- a) $v_e = \sqrt{\frac{2GM}{R}}$
- b) $v_e = \sqrt{\frac{2GM}{R^2}}$
- c) $v_e = \sqrt{\frac{2gM}{R}}$
- d) $v_e = \frac{2GM}{R}$

12) Imagine you wake up one morning to discover that Earth's magnetic field has begun one of its periodic reversals - something that happens roughly every 200,000-300,000 years. Over the next several thousand years, the fields will change and fracture into multiple magnetic poles. What would happen to compass navigation and auroras?

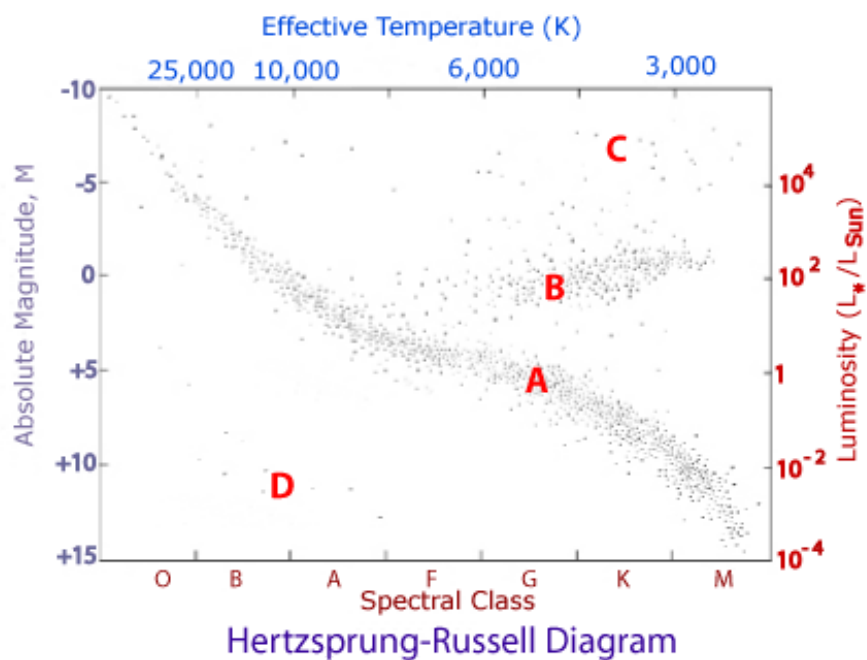
- a) Compasses would become dangerously unreliable - your compass needle might point toward another pole. Auroras would dance across unusual latitudes.
- b) Compasses would actually improve since there'd always be a closer magnetic pole to guide you. However, auroras would vanish completely.

- c) Compasses would spin uselessly as competing magnetic poles cancel each other out across most of the planet. Auroras would remain only at the original north and south polar regions.
- d) Compasses would still generally point north-south, just with reduced precision. Auroras would intensify dramatically.
- 13) Pluto is located approximately 40 AU (astronomical units) away from the Sun. How much more light from the Sun do we get at the Earth compared to Pluto?
- a) 20 times more
 b) 40 times more
 c) 400 times more
 d) 1600 times more
- 14) Using the same information from question 14, and assuming circular orbits, what is the orbital period of Pluto around the Sun in Earth years? You can use Kepler's Third Law which when written out says that $T^2 \propto a^3$ (the square of the orbital period is proportional to the cube of the semi-major axis of the orbit).
- a) 0.004 years
 b) 40 years
 c) 253 years
 d) 64 031 years
- 15) The constellation shown below was already known in Mesopotamia 5200 years ago. At that time, it had particular significance by marking the summer solstice point. Which constellation is this?



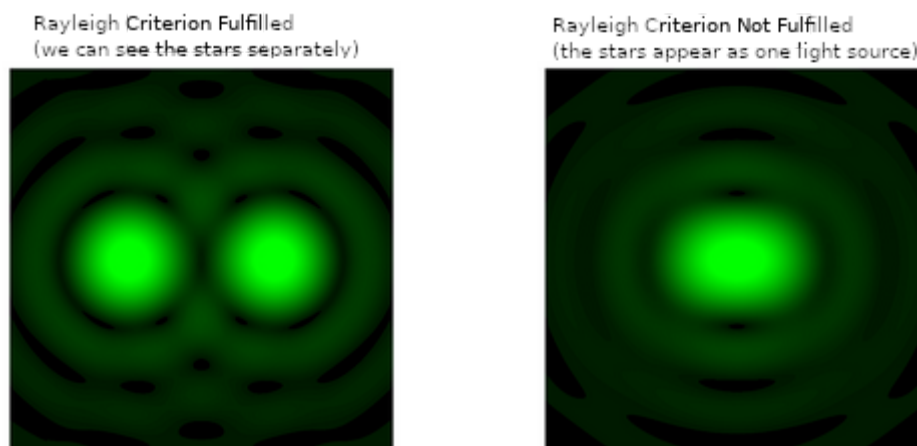
- a) Leo
- b) Ursa Major
- c) Canis Major
- d) Andromeda

16) Knowing that our Sun can be found on the main sequence in an HR diagram, what is its spectral class as read off from the provided plot?



- a) O
- b) B
- c) G
- d) M

- 17) The two stars in the binary system Gamma Leonis are 3 arcsec apart from each other at a certain point in time. Can we use an amateur telescope with an aperture diameter of 25mm to see them as two distinct stars, and why? Assume that the wavelength of light is 550nm on average, and that observing conditions are otherwise ideal. (1 deg = 3600 arcsec)



- a) Yes - the Rayleigh criterion gives an angle smaller than the separation, which means we can resolve the two stars.
 - b) No - the Rayleigh criterion gives an angle smaller than the separation, which means that we cannot resolve the two stars.
 - c) Yes - the Rayleigh criterion gives an angle greater than the separation, which means we can resolve the two stars.
 - d) No - the Rayleigh criterion gives an angle greater than the separation, which means we cannot resolve the two stars.
- 18) The space probe Juno has been orbiting Jupiter since 2016 and has given us a unique insight into Jupiter's composition, magnetic field, and the potential presence of a rocky core among many other topics. Jupiter's average distance to the sun is 5,20AU. Assume that the Earth and Jupiter are at their closest, and Juno's distance from Jupiter is 2,700,000 km directly towards the Earth. When sending a signal from earth, what is the earliest reply we can receive from Juno?
(Question made by Nataniel Skjøndal-Bar, competitor at IOAA 2023).

- a) Impossible to know
- b) 34,8 minutes
- c) 1 hour and 9,7 minutes
- d) 1 hour and 19 minutes

19) The Earth's escape velocity is around 11 km/s. Your friend is worried that because of global warming, we will lose a significant fraction of our atmosphere. The typical velocity of gas molecules is given by $v = \sqrt{3kT/m}$, where k is Boltzmann's constant (1.38×10^{-23} J/K), T is temperature in Kelvin, and m is the molecular mass. Using this formula, which response best addresses your friend's concern?

- a) Even with significant temperature increases from global warming, atmospheric molecules like nitrogen ($m = 4.65 \times 10^{-26}$ kg) and oxygen ($m = 5.31 \times 10^{-26}$ kg) have a typical velocity far below 11 km/s, so atmospheric loss is negligible.
- b) The relationship between velocity and molecular mass shows that lighter molecules escape more easily, so we'll lose oxygen before nitrogen due to global warming.
- c) Since v is proportional to $\sqrt{T}$, a modest rise in temperature increases the molecular speed to escape velocity.
- d) Global warming increases T immensely, which decreases the ratio v_{escape}/v so much that molecules easily escape Earth's atmosphere.

20) One of Mars's moons, Phobos, has an orbital diameter that is 41 times smaller than our Moon's, and an orbital period that is 86 times shorter than our Moon's around Earth. Also knowing that Mars's radius is approximately 53% that of Earth's, which of these values corresponds most closely to the strength of Mars's gravitational field?

- a) $0.13 \frac{N}{kg}$
- b) $3.75 \frac{N}{kg}$
- c) $9.81 \frac{N}{kg}$
- d) $25.86 \frac{N}{kg}$