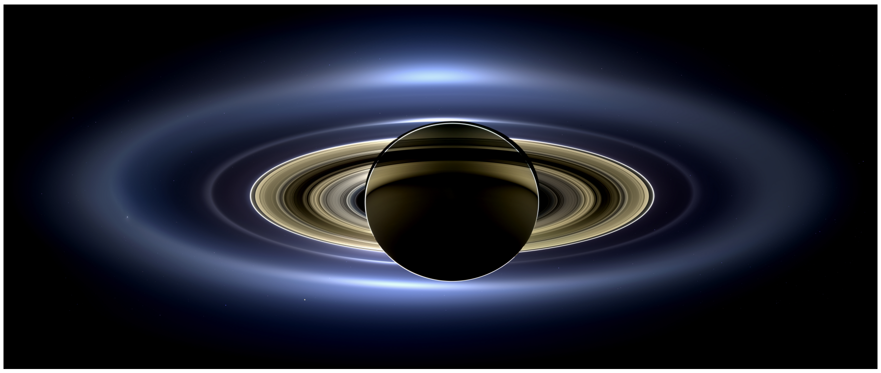
Science Olympiad
Solar System
Sample Test

2025-2026 Season



Written by: Aditya Shah, *adityashah108@gmail.com*

Note: if you are a student taking this exam for practice, then you are in the right place. If you are looking for the annotated test and event guide, then look here.

Section A [20 points]

Each multiple choice question has only one answer and is worth 1 point for a total of 20 points.

1. Which of the following terms best describes the Sun?
   - A. A moon
   - B. A planet
   - C. A star
   - D. A galaxy
   - E. A constellation
2. How many planets are in the Solar System? *Note: this does not include dwarf planets.*
   - A. 4
   - B. 7
   - C. 8
   - D. 9
   - E. None of the above
3. In what portion of the Solar System is Ceres located?
   - A. Between Mercury and the Sun
   - B. In the Asteroid Belt
   - C. In the Kuiper Belt
   - D. In the Oort Cloud
   - E. Trick question; Ceres is not located in the Solar System
4. What force keeps planets in orbit around the Sun?
   - A. Gravitational force
   - B. Electromagnetic force
   - C. Weak nuclear force
   - D. Strong nuclear force
5. Which of the following planets is the largest, by volume?
   - A. Mercury
   - B. Jupiter
   - C. Saturn
   - D. Uranus
   - E. Neptune
6. Which of the following planets has the highest average density?
   - A. Mercury
   - B. Jupiter
   - C. Saturn
   - D. Uranus
   - E. Neptune
7. Which of the following planets is the closest, on average, to the Sun?
   - A. Mercury
   - B. Jupiter
   - C. Saturn
   - D. Uranus
   - E. Neptune
8. The most prevalent element in Jupiter's atmosphere is ____________.
   - A. Iron
   - B. Oxygen
   - C. Hydrogen
   - D. Carbon
   - E. Silicon
   - F. None of the above
9. Triton is a moon of ____________.
   - A. Mercury
   - B. Jupiter
   - C. Saturn
   - D. Uranus
   - E. Neptune
10. If you double the distance between two objects, the gravitational force between those objects will:
    - A. Become 1/4 of what it used to be
    - B. Become 1/2 of what it used to be
    - C. Stay the same
    - D. Increase by a factor of 2
    - E. Increase by a factor of 4
11. True or false: a cool planet's blackbody spectrum will peak at a longer wavelength than that of a hot planet.
    - A. True
    - B. False

12. Which of the following is inside the Solar System?
    - A. 51 Pegasi
    - B. 486958 Arrokoth
    - C. HD 209458
    - D. HL Tauri
13. Which of the following is a comet?
    - A. HD 209458
    - B. HL Tauri
    - C. 25143 Itokawa
    - D. Tempel 1
14. The Great Dark Spot is an atmospheric feature on ___________.
    - A. Mercury
    - B. Jupiter
    - C. Saturn
    - D. Uranus
    - E. Neptune
15. True or false: Earth's Moon is thought to have formed before Earth itself. Later, it was gravitationally captured by Earth.
    - A. True
    - B. False
16. True or false: When an object is moving towards us, we say light from that object is blueshifted.
    - A. True
    - B. False
17. True or false: 51 Pegasi b is considered a "hot Jupiter".
    - A. True
    - B. False
18. Most long-period comets are thought to originate in the ___________.
    - A. Asteroid Belt
    - B. Kuiper Belt
    - C. Oort Cloud
    - D. None of the above
19. *Cassini* is a mission that primarily studied ___________ and its system.
    - A. Mercury
    - B. Jupiter
    - C. Saturn
    - D. Uranus
    - E. 486958 Arrokoth
    - F. 25143 Itokawa
20. Which of the following portions of the electromagnetic spectrum has the highest frequency?
    - A. Infrared
    - B. Visible
    - C. Microwave
    - D. X-rays
    - E. Radio

Section B [125 points]

When applicable, use the Image Set to answer the following questions. Unless otherwise specified, each part of each question is worth 2 points.

21. (3 points) Order the following images by how far the objects they depict are from the Sun, from closest to farthest: 1, 2, 3, 4, 5

22. (a) Which object is shown in Image 1?
    (b) What spacecraft collected the data to create this image?
    (c) This spacecraft flew by the object instead of orbiting it to observe it for more time. Why?
    (d) In the image, we see a large heart-shaped feature. What is its name?

23. (a) Which object is shown in Image 2?
    (b) This object is well-known for its beautiful ring system. What are the rings made of?
    (c) What causes the pale yellow color of this object's atmosphere?

24. (a) One of the images on the Image Sheet shows a comet. Which one?
    (b) What is the name of this comet?
    (c) What mission(s) collected the data to create this image?

25. (a) What planet is the Great Red Spot on?
    (b) Briefly describe what the Great Red Spot is.
    (c) What image shows the Great Red Spot?
    (d) What mission(s) collected the data to create this image?
    (e) In what portion(s) of the electromagnetic spectrum (e.g., visible, infrared, etc.) was/were the data in this image collected?

26. (a) Which object is shown in Image 4?
    (b) What mission(s) collected the data to create this image?
    (c) How do scientists believe this object formed?

27. (a) One of the objects on the rules was visited by a spacecraft called *Hayabusa*. What is the name of that object?
    (b) What space agency/country led the development of *Hayabusa*?
    (c) What image shows this object?

28. (a) There are two images that show Mercury on the Image Sheet. Which ones are they?
    (b) What mission(s) collected the data to create these images?
    (c) Which of the following best describes Mercury: (1) rocky/metallic or (2) gaseous?

29. (a) Images 7 and 8 show different surface features on the same object. Which object?
    (b) The surface feature in the red dashed circle in Image 7 is a mountain. What is its name?
    (c) In Image 7, the mountain itself has very few craters, but the area surrounding it has many small craters. What does this imply about the age of the mountain compared to the age of the surrounding terrain?
    (d) Image 8 shows a surface feature called Kwanzaa Tholus. Briefly explain what a tholus is.
    (e) Using the color bar in Image 8, estimate the height, in kilometers, of Kwanzaa Tholus.

(f) Scientists believe that Kwanzaa Tholus was the same height as the mountain in Image 7 when they first formed. Based on this information, which do you think is older: (1) Kwanzaa Tholus or (2) the mountain in Image 7? Explain your reasoning.

30. (a) Image 9 shows a portion of the surface of Triton. What image shows the planet that this object is a moon of?
(b) The type of terrain shown in Image 9 has a specific name. What is it?
(c) What mission(s) collected the data to create Image 9?
(d) There is one other image of Triton on the Image Sheet. Which one is it?
(e) Scientists believe Triton was gravitationally captured by its planet after forming. Name two pieces of evidence that support this theory.

31. (a) What image shows HL Tauri?
(b) What mission(s) collected the data to create this image?
(c) In what portion(s) of the electromagnetic spectrum (e.g., visible, infrared, etc.) was/were the data in this image collected?
(d) If we observed HL Tauri in visible light, we would not be able to clearly make out the central star and protoplanetary disk. Why is that the case?
(e) Scientists believe that the gaps visible in the disk may be due to planets forming. Why would the formation of planets in the disk cause gaps?

32. (a) Which object is shown in Image 10?
(b) What mission(s) collected the data to create this image?
(c) Image 10 happens to be a false-color image. In your own words, please explain what that means.
(d) There are a few circular splotches on this object, particularly towards the right side. Three of them have been indicated by red arrows. What are these circular splotches?
(e) There are also several labeled objects (e.g., Rosalind, Belinda, Puck, etc.) whose motion is shown with curved white arrows. What type of object (e.g., asteroid, planet, moon, etc.) are these?

33. (a) Image 12 shows a plot associated with the discovery an object. Which one?
(b) Briefly explain what values are plotted on the x and y axes.

34. (a) Image 14 shows storms near Jupiter's north pole in visible light, microwave, and infrared. Which panels (left, center, and right) correspond to which portions of the electromagnetic spectrum?
(b) What mission(s) collected the data to create this image?
(c) What *instruments* on these mission(s) were used to collect the data?
(d) Of these three wavelengths (visible light, microwave, and infrared), order them by the depth into Jupiter's atmosphere that they see, from shallowest to deepest.
(e) The central storm is visible in the middle and right panels, but not as much in the left panel. What does this imply about the structure/depth of that storm?

35. (a) Images 18 and 19 show different surface features on the same object. Which object?
(b) What mission(s) collected the data to create this image?
(c) Is the surface feature in Image 18 a crater or mountain? How can you tell?
(d) The surface feature in Image 19 is a crater. What is its name?
(e) Which surface feature has the larger diameter: the one in Image 18 or 19? Explain your reasoning.

36. (a) Image 20 shows an exoplanet discovered by through the *transit* method. What is its name?
(b) Is Image 20 a photograph or an artist illustration? How do you know?

37. (a) Every object/system on the rules is represented on the Image Sheet except for one. Which one?
(b) Give a brief, one-sentence description of what this object/system is.

Section C [70 points]

For the following questions, please explain your answers (i.e., do not just write "yes" or "no").

38. (16 points) Imagine that you are part of a team studying small, icy objects in the Solar System. Preliminary measurements of a new object indicate that it is made up of some combination of ice ($\rho = 0.9$ g/cm^3) and rock ($\rho = 3.6$ g/cm^3) and has an overall density of 1.8 g/cm^3.
    (a) (3 points) What fraction of the object's *volume* is ice?
    (b) (3 points) What fraction of this object's *mass* is ice?
    (c) (3 points) Suppose that the object is completely differentiated with a rocky core surrounded by ice. What is the ratio of the radius of the core to the radius of the object?
    (d) (2 points) If the ice and rock were distributed uniformly throughout the object (i.e., there was no differentiation), would the moment of inertia of the object be higher, lower, or the same compared to the case in part (c)? Explain.
    (e) (3 points) After more analysis, your team realizes that the mass of the object was underestimated by 10%, but the original radius was correct. Would your answers to parts (a), (b), and (c) of this question increase, decrease, or stay the same?
    (f) (2 points) In part (c), we assumed that the object was completely differentiated. Does this assumption become better or worse as the size of the object increases?

39. (12 points) Your friend at NASA is planning a mission to study Neptune, but they are not sure whether to power it using RTGs or solar panels. They've asked you for some advice.
    (a) (3 points) In your own words, explain what an RTG is. What are some of the advantages and disadvantages of using an RTG over solar panels?
    (b) (3 points) The amount of available sunlight is critical to evaluating the effectiveness of solar panels. If the intensity of sunlight at Earth is $\sim$1350 W/m^2 and Neptune is 30 AU from the Sun, what is the intensity of sunlight at Neptune, in W/m^2?
    (c) (4 points) Your friend tells you that their spacecraft will require $\sim$150 W to operate safely. Modern solar panels in space operate at about 20% efficiency and have a mass of $\sim$1 kg/m^2. Estimate the surface area and mass of the solar panels that would be required to power your friend's spacecraft.
    (d) (2 points) Let's put it all together. In your opinion, would you recommend that your friend uses solar panels or an RTG? Explain your choice.

40. (22 points) When a planet is in thermal equilibrium, the power it absorbs is equal to the power it emits. However, Saturn's total luminosity is $\sim$2 times greater than the power that it absorbs from the Sun. One theory is that the excess energy comes from liquid hydrogen and helium inside Saturn demix (i.e., separate) and the helium droplets fall down as "rain", converting their gravitational potential energy to heat.
    (a) (2 points) Scientists do not think Jupiter will exhibit H/He demixing as much as Saturn. Part of the reason is that Jupiter's interior is much hotter than Saturn's. Explain.
    (b) (2 points) Why do the helium droplets sink towards the center of Saturn instead of staying where they are?
    (c) (10 points) Estimate, to the nearest few orders of magnitude, the energy, in Joules, that would be released if *all* of the helium from Saturn's envelope rained onto the surface of the rocky core of Saturn. This is intentionally written as an open-ended problem with incomplete information; use your knowledge of planetary science to make reasonable assumptions and guesses. Since this is just an order-of-magnitude estimate, the exact values don't matter as much. Some helpful information:
        - Saturn's total mass is $\sim 100 M_\oplus$ and its radius is $\sim 6 \times 10^7$ meters
        - $G = 7 \times 10^{-11}$ N m^2 kg^{-2} and 1 $M_\oplus = 6 \times 10^{24}$ kg

(d) (6 points) Estimate, to the nearest order of magnitude, the *excess* energy Saturn has emitted over its lifetime, in Joules. Some helpful information:

- The intensity of sunlight at Earth is $\sim$1350 W/m^2
- Saturn is about 9.5 AU from the Sun and absorbs 60% of the light that hits it
- 1 year $= 3 \times 10^7$ seconds

(e) (2 points) Compare your answers to the previous two parts and comment on whether you think helium rain is a possible candidate for Saturn's excess luminosity.

Note: this question was adapted (essentially copied) from Question 4 on Problem Set 2 of Eugene Chiang's Planetary Astrophysics class at UC Berkeley.

41. (20 points) As a star forms, the material around it forms a rotating disk of gas and dust.

(a) (2 points) Many objects in the universe are spinning disks. In your own words, explain why.

(b) (2 points) Planets form inside this disk. The two leading theories of planet formation are the core accretion and disk instability models. Briefly describe what the core accretion model is.

Now, we'll take a closer look at the disk instability model, in which a local overdensity in the disk collapses in on itself to form a planet. Within the disk, multiple forces are at play, such as self-gravity, shear, and pressure. Consider a small chunk of the disk that has radius Δr, centered at a distance R from the star. Ignoring dimensionless factors of order unity, the three timescales in the disk at R are

$$t_{\text{grav}} \sim \sqrt{\frac{\Delta r}{G\Sigma}} \qquad t_{\text{shear}} \sim \frac{1}{\Omega} \qquad t_{\text{pr}} \sim \frac{\Delta r}{c_{\text{s}}}$$

where G is the gravitational constant, Σ is the surface mass density of the disk, c_{s} is the speed of sound in the disk, and Ω is the angular velocity of the disk at R.

(c) (3 points) What causes shear forces in a protoplanetary disk? *Hint: think about Kepler's third law*

(d) (1 point) Within the disk, which will dominate: the force with the shortest or longest timescale?

(e) (3 points) Physically, what is happening when t_{shear} and t_{pr} are both much less than t_{grav}? Do these conditions make it easier or harder for a chunk of the disk to collapse?

(f) (7 points) One model for planet formation involves a local overdensity in this disk collapsing to form the planet. Using the timescales above, derive Toomre's instability criterion: $Q \sim \frac{c_{\text{s}}\Omega}{G\Sigma} < 1$.

(g) (2 points) Having $Q < 1$ at the start of the collapse is a necessary, but not sufficient condition for disk fragmentation. What else do we need, and why?

42. *Tiebreaker #1:* When preparing for this event, you probably studied some concepts that weren't covered explicitly on this exam, simply because this exam can't be infinitely long. Choose one of them and write about it in as much detail as you can.