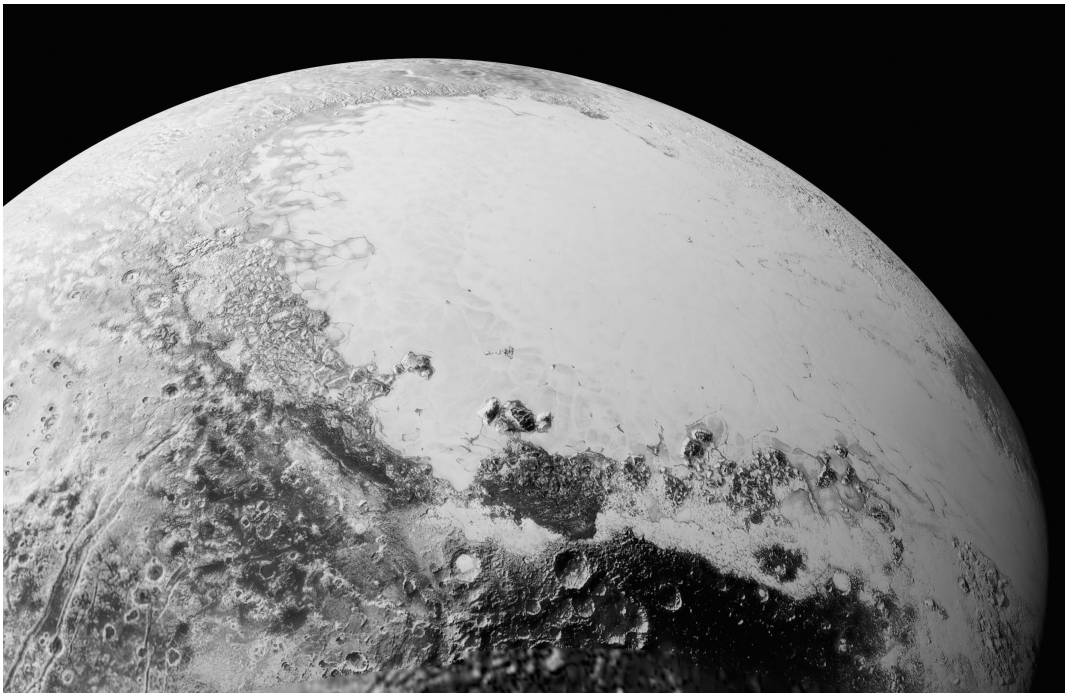
Science Olympiad
Solar System B
UT Regional 2026

March 7, 2026
Austin, TX



Directions:

- You are allowed to bring in **two** 8.5" × 11" sheets of paper with information on both sides.
- This exam and image sheet are class sets. Please write all answers on your answer sheet only.
- You can take apart the test as long as you restaple the pages in the correct order at the end.
- This exam consists of **three sections** containing questions worth **200 points**.
- There is no penalty for wrong answers.
- The exam will be available online at `atxscioly.org` and `adi1008.github.io` after the tournament.
- Above all else, just believe!

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

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. 5
   C. 6
   D. 7
   E. 8
   F. 9
   G. None of the above

3. In what portion of the Solar System is Jupiter located?
   A. Between Mercury and the Sun
   B. In the Asteroid Belt
   C. Between the Asteroid Belt and the Kuiper Belt
   D. In the Kuiper Belt
   E. In the Oort Cloud

4. What force keeps planets in orbit around the Sun?
   A. Electromagnetic force
   B. Weak nuclear force
   C. Strong nuclear force
   D. Gravitational force
   E. None of the above

5. Which of the following lists objects by their distance to the Sun, from closest to farthest?
   A. Jupiter, Saturn, Uranus, Neptune
   B. Jupiter, Saturn, Neptune, Uranus
   C. Saturn, Jupiter, Uranus, Neptune
   D. Saturn, Jupiter, Neptune, Uranus

6. Out of all the planets in our Solar System, _____ has the largest ring system.
   A. Jupiter
   B. Saturn
   C. Uranus
   D. Neptune
   E. Pluto

7. Which of the following spacecraft have visited Pluto?
   A. Voyager 2
   B. Galileo
   C. Cassini
   D. Dawn
   E. New Horizons

8. Of the following objects, which one was visited by the *Dawn* spacecraft?
   A. Mercury
   B. Ceres
   C. Neptune
   D. Pluto
   E. HL Tauri

9. Imagine a planet of mass M and radius R. If we double the radius and keep the mass the same, by what factor does the surface gravity (i.e., the acceleration due to gravity at the surface) of the planet change?
   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

10. Two planets, Planet A and Planet B, have the same overall density. However, the radius of Planet A is 3 times larger than that of Planet B. How many times more massive is Planet A than Planet B?
    A. $\sqrt{3}$
    B. 3
    C. $\sqrt{27}$
    D. 9
    E. 27

11. The first exoplanet orbiting a Sun-like star was detected around _____.
    A. HL Tauri
    B. HD 209458
    C. 51 Pegasi
    D. Beta Pictoris
    E. 486958 Arrokoth

12. If you double the distance between two objects *and* triple the mass of *both* objects, the gravitational force between those objects will:
    A. Become 1/9 of what it used to be
    B. Become 2/9 of what it used to be
    C. Become 4/9 of what it used to be
    D. Increase by a factor of 2
    E. Increase by a factor of 9/4
    F. Increase by a factor of 9/2

13. Consider a planet in a circular orbit around a star of mass 4 $M_\odot$ at a distance of 2 AU. What is its period, in Earth years?
    A. 0.5 Earth years
    B. $1/\sqrt{2}$ Earth years
    C. 1 Earth year
    D. $\sqrt{2}$ Earth years
    E. $2\sqrt{2}$ Earth years

14. True or false: Tempel 1 is inside the Solar System.
    A. True
    B. False

15. Which of the following is a dwarf planet?
    A. Triton
    B. Pluto
    C. 25143 Itokawa
    D. HL Tauri

16. Mare Tranquillitatis (the Sea of Tranquility), where Apollo 11 landed, is a surface feature on _____.
    A. Mercury
    B. Ceres
    C. Triton
    D. Earth's Moon
    E. 25143 Itokawa

17. Which of the following portions of the electromagnetic spectrum has the longest wavelength?
    A. Infrared
    B. Visible
    C. Microwave
    D. X-rays
    E. Radio

18. The first widely-accepted exoplanet detected via the transit method orbits _____.
    A. HL Tauri
    B. HD 209458
    C. 51 Pegasi
    D. Beta Pictoris
    E. 486958 Arrokoth

19. True or false: Beyond the *frost line*, the temperature is too high for compounds like water, ammonia, and methane to exist as solids.
    A. True
    B. False

20. Which of the following missions studied a comet?
    A. Juno
    B. Dawn
    C. Hayabusa
    D. Deep Impact

Section B [112 points]

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

21. Order Images 1-5 by how far the objects they depict are from the Sun, from closest to farthest.

22. Order Images 1-5 by how large the objects they depict are, from smallest to largest.

23. (a) Image 1 shows a planet in the Solar System. What is its name?
    (b) This planet has a beautiful ring system. What material (e.g., iron, hydrogen, carbon dioxide, etc.) is its rings primarily made of?
    (c) Suppose I wanted to visit this planet. Would it have a clearly defined surface for me to land on?
    (d) There is one other image of this planet on the image sheet. Which one is it?

24. (a) Image 2 shows an atmospheric feature on an object in the Solar System. Which object?
    (b) What spacecraft or telescope collected the data to create this image?
    (c) There is one other image of this object on the image sheet. Which one is it?

25. (a) What image shows Neptune?
    (b) Is this Neptune denser than the object shown in Image 4?
    (c) Briefly describe how this planet was discovered.

26. (a) What object is shown in Image 3?
    (b) This object has been described as an "embryonic planet." What does that mean?
    (c) The crater in this image is quite famous. What is its name?
    (d) How did the bright spots in this crater (which are visible in this image) form?

27. (a) What spacecraft or telescope collected the data to create Image 4?
    (b) The mission from the previous part ended in 2015. How did NASA chose to end it?
    (c) There is currently one spacecraft still studying this object. What is the name of that spacecraft?

28. (a) What object is shown in Image 5?
    (b) What spacecraft or telescope collected the data to create this image?
    (c) There is one other image of this object on the image sheet. Which one is it?

29. (a) What image shows a comet?
    (b) This comet was visited by a spacecraft focused on its subsurface material. What information does the comet's subsurface material provide that the comet's surface might not?

30. (a) What object is shown in Image 7?
    (b) This object is tidally locked to the object it orbits. In your own words, explain what that means.
    (c) In Image 7, we can see many dark spots, which scientists call *maria*. What are maria?

31. (a) What object is shown in Image 8?
    (b) What spacecraft or telescope collected the data to create this image?
    (c) This image contains a small white dot and a small black dot. What are they?

32. (a) What object is shown in Image 14?
    (b) What spacecraft or telescope collected the data to create this image?

33. (a) What image shows cantaloupe terrain?
    (b) What moon is this terrain found on?
    (c) What image, aside from the one in part (a), shows this moon?
    (d) What image shows the planet around which this moon orbits?

34. (a) What image shows a system containing a directly-imaged exoplanet?
    (b) In what portion(s) of the electromagnetic spectrum (e.g., visible, infrared, etc.) was/were the data in this image collected?
    (c) Do we think this planet is older or younger than Earth? Explain.

35. (a) Image 16 shows an artist's illustration of an exoplanet called 51 Pegasi b. Through what detection technique was this exoplanet first discovered?
    (b) 51 Pegasi b is around the same mass as Jupiter but orbits extremely close to its parent star (unlike Jupiter). What is the leading explanation for how 51 Pegasi b ended up so close to its star?

36. (a) What object is shown in Image 17?
    (b) What spacecraft or telescope collected the data to create this image?
    (c) What is the white dot towards the bottom of the object in the image?

37. (a) Image 9 shows a fault running through two craters. What other image shows the same object?
    (b) Measurements of the surface indicate that the craters are shorter in the direction perpendicular to the fault. Based on this information, do you think these surface features are the result of compression or tension?
    (c) Scientists believe that these surface features may be the result of Mercury cooling. How could Mercury cooling produce this type of surface feature?

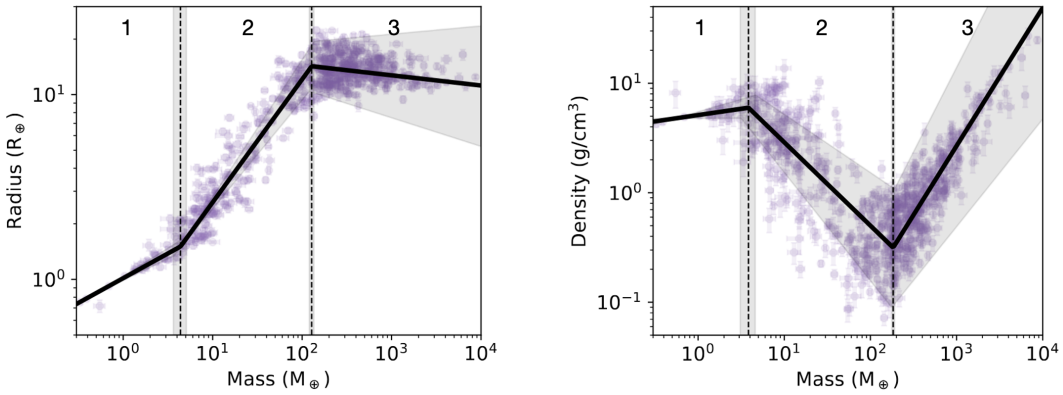
38. (a) Image 10 shows a crater on the Moon. The bright material directly surrounding the crater is called the ejecta blanket. How is the ejecta blanket formed?
    (b) Why is the ejecta blanket much brighter than the surrounding area?
    (c) As we move farther from the central crater, does the thickness of the ejecta blanket increase or decrease?
    (d) Suppose measurements indicate that the ejecta blanket is more expansive on the right side of the crater than the left. What does that imply about the angle at which the meteorite hit the moon?

39. Image 11 shows the *effective* surface gravity (taking rotation into account) on an object, assuming both lobes in the image have the same uniform density. The red dot marks the object's center of mass, and the rotation axis passes through the red dot and points out of the page.
    (a) Which object is depicted in Image 11?
    (b) What spacecraft or telescope collected the data to create this image?
    (c) Explain why the effective surface gravity is higher at point C than on the small lobe.
    (d) Point B lies in the narrow "neck" region connecting the two lobes. Explain why this makes the effective surface gravity especially low there.
    (e) Point A is near an outer tip of the object. If the object's rotation were to slow down, would the effective surface gravity at point A increase or decrease? Briefly explain.

Section C [68 points]

This section consists of three questions and one tiebreaker at the end. To make taking the test easier, each question is on its own page, so make sure to flip the pages to look at everything. Please explain your answers (i.e., do not just write "yes" or "no").

40. (20 points) The figure below, taken from Müller *et al.* (2024), shows how the radius (R, left panel) and density (ρ, right panel) of exoplanets depend on their mass. The dots represent individual planets, while the thick black lines represent trends in three different "regions" of the plot (numbered 1-3).



(a) (3 points) Which regions (1-3) would Mercury, Neptune, and Jupiter fall into?

(b) (2 points) Suppose you measure the mass and radius of a newly discovered planet. Does this uniquely determine what the planet is made of? Why or why not?

(c) (3 points) These trends are often described using an equation in the form $R \propto M^x$. Derive what the value of x would be if we assume the planet to be a constant-density, homogeneous sphere.

(d) (4 points) Suppose that within a given region, the trends are described by $R \propto M^x$ and $\rho \propto M^y$. Starting from $\rho = M/V$ with $V = \frac{4}{3}\pi R^3$, derive a relation between the exponents x and y.

(e) (4 points) In region 2, the radii increase with mass, but the densities decrease. Why? Frame your answer in terms of planet formation and structure.

(f) (4 points) In region 3, the radii change very little with increasing mass (and may even decrease), while the densities rise sharply. Why?

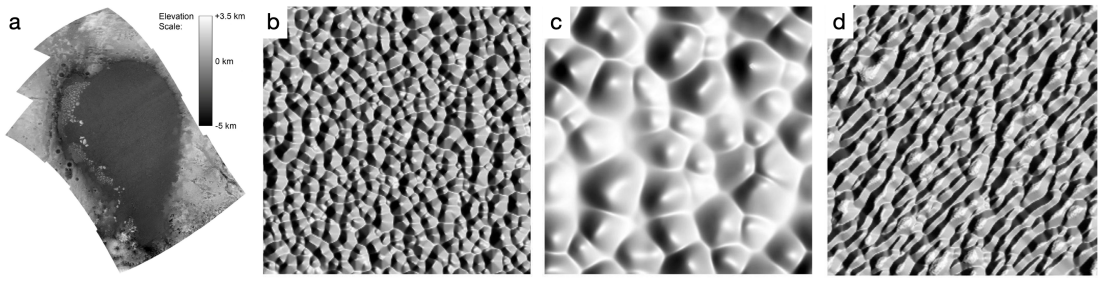
41. (22 points) Sputnik Planitia is an enormous deposit of different types of ice on Pluto.

    (a) (2 points) Sputnik Planitia has very few craters. What does this imply about its surface's age?

    (b) (4 points) Name three chemical compounds that the ice in Sputnik Planitia consists of. Specify which of the three is most prevalent.

    (c) (2 points) Sputnik Planitia is home to polygonal cells which are covered by pits. How are the polygonal cells thought to be formed?

    Let's take a closer look at the pits in Sputnik Planitia. Panel (a) is a "digital elevation model" (i.e., an elevation map) of Sputnik Planitia taken from White *et al.* (2017). Panels (b) through (d) show simulations of pit formation adapted from Moore *et al.* (2017).



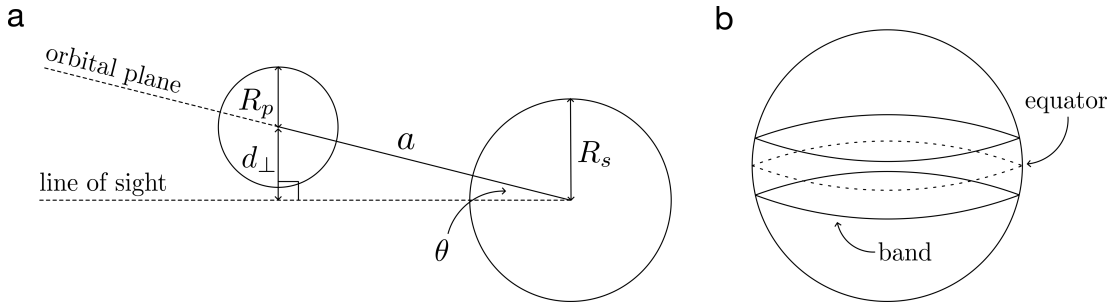
    (d) (4 points) Would you characterize the interior of Sputnik Planitia as flat or mountainous? What does this imply about the *viscosity* of the ices that make up that area of Sputnik Planitia?

    (e) (4 points) The formation and size of the pits is thought to be due to the balance between "sublimation deepening and ice flow infilling." Briefly describe how this could lead to pit formation.

    (f) (4 points) Panels (b) and (c) show simulations of pit formation. The conditions in the simulations were identical, except that in panel (c), the "slope diffusivity" (i.e., ability to move downhill to smooth out a steep slope) of the ice was 10 times higher than that in panel (b). How does that explain the change in pit size that we see?

    (g) (2 points) Some of the pits on Sputnik Planitia are several kilometers long, similar to those shown in panel (d). How are these elongated pit chains created within the "balance of sublimation and infilling" framework?

42. (26 points) The transit method detects exoplanets by measuring the dip in a star's brightness as a planet passes in front of it. The transit probability is often quoted as R_s/a, but where does this expression come from?



Consider a planet of radius R_p in a circular orbit of radius a around a star of radius R_s. Let θ be the angle between the orbital plane and our line of sight, where $\theta = 0°$ is edge-on and $\theta = 90°$ is face-on, as shown in panel (a) of the above figure.

(a) (2 points) From the diagram, $d_\perp$ is the perpendicular distance from the planet's center to the line of sight. Which of the following is equivalent to $d_\perp$? Choose from: $a\cos\theta$, $a\sin\theta$, and $a\tan\theta$.

(b) (4 points) We observe a transit when the planet's disk overlaps the star's disk. What is the maximum value of θ that allows for a transit? Answer in terms of R_s, R_p, a, and θ.

Imagine a unit sphere centered on the star. Each point on the sphere represents a possible direction from which an observer could look at the system. Because viewing directions are random, all points on this sphere are equally likely. All viewing directions that result in a transit form a band around the equator of the unit sphere, centered on the orbital plane, as shown in panel (b) of the above figure.

(c) (4 points) Write an expression for the area of the band in terms of only θ. *Hints: on a unit sphere, the area of a belt between heights $z = z_1$ and $z = z_2$ is $A_{\text{belt}} = 2\pi(z_2 - z_1)$ and a point at angle θ above the equator has height $z = \sin\theta$.*

(d) (4 points) The transit probability is the fraction of the sphere's surface covered by the band. Show that it is $(R_s + R_p)/a$. *Hint: the surface area of a unit sphere is 4π.*

(e) (4 points) In practice, the transit probability is often quoted simply as R_s/a, since we assume that R_p is much smaller than R_s. To the nearest order of magnitude, what would the error be if aliens tried observing a transit of Earth around the Sun using this approximation?

(f) (4 points) This expression for transit probability does not tell us the probability that we *detect* the transit. Why, and what is the difference between the two?

(g) (4 points) Let's put it all together. What types of planets (e.g., distance from star, planet size, type of parent star, etc.) is the transit method best suited to detect?

43. *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.