Science Olympiad
Solar System
UT Invitational 2025

October 25, 2025
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.
- 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 **154 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!

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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 Pluto 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; Pluto is outside of the Solar System

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 planets is the smallest, by volume?
   A. Mercury
   B. Jupiter
   C. Saturn
   D. Uranus
   E. Neptune

6. Which of the following planets has the lowest 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 Neptune's atmosphere is ___________.
   A. Iron
   B. Oxygen
   C. Carbon
   D. Hydrogen
   E. Silicon
   F. None of the above

9. If you double the distance between two objects *and* double the mass of *both* 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

10. 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

11. True or false: 25143 Itokawa is inside the Solar System.
    - A. True
    - B. False
12. Which of the following is a dwarf planet?
    - A. Mercury
    - B. Ceres
    - C. 486958 Arrokoth
13. Tombaugh Regio is a surface feature on ___________.
    - A. Jupiter
    - B. Saturn
    - C. Uranus
    - D. Neptune
    - E. Pluto
14. Through which detection method was 51 Pegasi b discovered?
    - A. Radial velocity
    - B. Transit
    - C. Direct imaging
    - D. None of the above
15. True or false: A Hot Jupiter's radius tends to be smaller than what it would be if it were much further away from its parent star.
    - A. True
    - B. False
16. Most long-period comets are thought to originate in the ___________.
    - A. Asteroid Belt
    - B. Kuiper Belt
    - C. Oort Cloud
17. *BepiColombo* is a mission that primarily studies ___________ and its system.
    - A. Mercury
    - B. Jupiter
    - C. Saturn
    - D. Uranus
    - E. 486958 Arrokoth
    - F. 25143 Itokawa
18. Which of the following portions of the electromagnetic spectrum has the lowest frequency?
    - A. Infrared
    - B. Visible
    - C. Microwave
    - D. X-rays
    - E. Radio
19. Which of the following cannot possibly be explained by a giant impact?
    - A. The formation of Earth's Moon
    - B. Triton's retrograde orbit
    - C. Uranus's extreme axial tilt
    - D. All of these are thought to be due to giant impacts
20. Planets in the Solar System primarily give off light in which portion of the electromagnetic spectrum?
    - A. Ultraviolet
    - B. Visible
    - C. Gamma-rays
    - D. X-rays
    - E. Infrared

Section B [80 points]

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

21. (2 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. (2 points) Order the following images by how large the objects they depict are, from smallest to largest: 1, 2, 5, 8, 12
23. (a) Image 1 shows the most massive planet in the Solar System. What is its name?
    (b) This planet has a red spot on it, which is aptly named the Great Red Spot. What is the Great Red Spot?
24. (a) What object is shown in Image 2?
    (b) What material (e.g., iron, hydrogen, carbon dioxide, etc.) are the rings in this photograph primarily made of?
    (c) What spacecraft or telescope collected the data to create this image?
25. (a) What object is shown in Image 3?
    (b) What spacecraft or telescope collected the data to create this image?
    (c) This object is the only planet in the Solar System that was not discovered through direct observation. Briefly describe how this object was discovered.
26. (a) What object is shown in Image 4?
    (b) What spacecraft or telescope collected the data to create this image?
27. (a) Image 5 was created using data from *BepiColombo*. What object is shown in Image 5?
    (b) Eminescu (towards the top right of the image) is a crater notable for containing "hollows", which are landforms unique to this object. Briefly describe what hollows are.
    (c) There is one other image of Eminescu on the image sheet. Which one is it?
    (d) Based on the amount of superimposed craters in Eminescu from the previous part's image, do you think Eminescu is young or old? How can you tell?
28. (a) There is one comet on this year's rules. What is its name?
    (b) What image shows this object?
29. (a) Image 12 shows Pluto. What spacecraft or telescope collected the data to create this image?
    (b) In 2006, the IAU reclassified Pluto as a dwarf planet instead of a planet. (RIP.) What was their reasoning?
30. (a) What object is shown in Image 14?
    (b) On the right half of the image, there is a smooth plain. What is the name of that plain?
    (c) This plain is covered with large glaciers. What material (e.g., iron, hydrogen, carbon dioxide, etc.) are these glaciers made of?
31. (a) Which image shows the object that *New Horizons* visited after Pluto?
    (b) This object is thought to have tholins on it. Briefly describe what tholins are and how they form.
32. (a) Image 7 shows Occator crater. What object is this crater on?
    (b) What do scientists believe causes the bright spots visible in this crater?

(c) There is one other image of this object on the image sheet. Which one is it?

(d) What spacecraft or telescope collected the data to create both of these images?

33. (a) Image 8 shows the only asteroid on this year's rules. What is its name?

    (b) This asteroid is made of two distinct parts that have significantly different densities. What does this imply about the formation of this asteroid?

34. (a) Image 9 shows an extrasolar system. What is its name?

    (b) This system shows an excess of infrared emission compared to normal stars of its type. What do scientists believe causes this?

35. (a) Image 13 shows a surface feature called Dorsa Geike. What object is this surface feature on?

    (b) Dorsa Geike is a wrinkle ridge. Briefly describe what a wrinkle ridge is.

36. (a) Cantaloupe terrain is only known to exist on one object. Which one is it?

    (b) Which image shows cantaloupe terrain?

    (c) What spacecraft or telescope collected the data to create this image?

37. (a) Image 17 shows data associated with one of the extrasolar systems on this year's rules. Which one?

    (b) This system has the first exoplanet detected through more than one method. Image 17 shows that one is the transit method; what is the other?

Section C [54 points]

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

38. (12 points) Mercury is notable for having an unusually large core relative to its size, which is closely tied to how Mercury formed. Most theories fall into one of two camps: (1) "chaotic" models, which involve one or more distinct, violent collisions between Mercury and other objects, and (2) "orderly" processes, which say that Mercury formed through different processes than the other terrestrial planets.

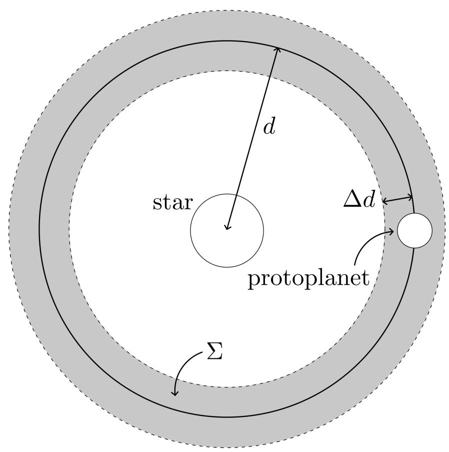
    (a) (4 points) Until MESSENGER visited Mercury, it was difficult to get data to test many of these hypotheses. Briefly describe why Mercury's proximity to the Sun makes it difficult to send spacecraft there in terms of (i) thermal requirements and (ii) propulsion.

    (b) (4 points) One "orderly" process hypothesizes that much of proto-Mercury's crust/mantle was gradually "evaporated" away by an energetic young Sun. MESSENGER data indicates that present-day Mercury has higher-than-expected abundances of moderately volatile materials (e.g., potassium). Does this discovery strengthen or weaken this hypothesis? Explain.

    (c) (4 points) Many of the "chaotic" models struggle with re-accretion of debris. What does this mean? Name one possible solution/workaround to this problem.

39. (12 points) One of the ways planet cores are thought to build up is through planetesimals colliding and merging with each other to eventually form larger protoplanets.

    (a) (2 points) As planetesimals grow, observed collision rates exceed what you would predict from their physical sizes alone. This is due to *gravitational focusing*. Briefly explain what that is.



Protoplanets cannot grow forever; at some point, they have accreted all of the nearby solid material and growth stalls at the *isolation mass* $M_{\rm iso}$. The image above shows a protoplanet of mass M_p orbiting a star of mass $M_{\rm s}$ at distance d. The protoplanet mainly "feeds" from a narrow annulus around d, which is shown in gray.

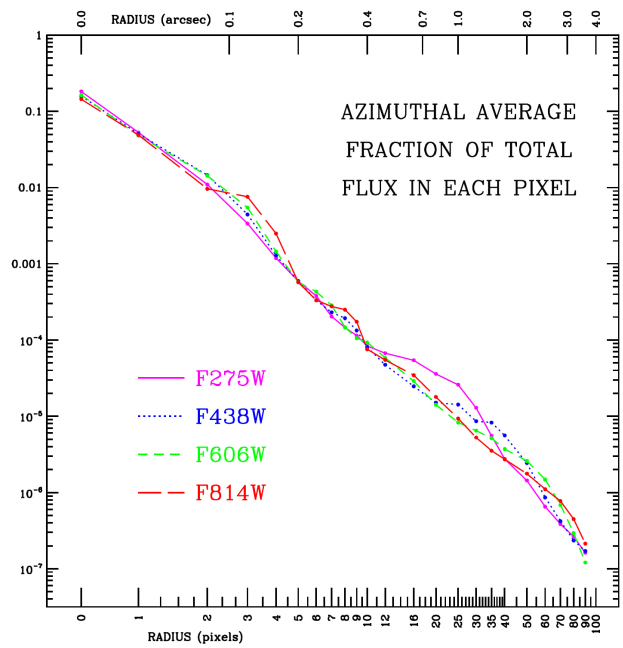
    (b) (2 points) Since $d \gg \Delta d$, we can treat the feeding zone as a narrow annulus of area $A \approx 2\pi d \times (2\Delta d)$ with constant surface mass density Σ. Write an expression for the total mass within the feeding zone, $M_{\rm feed}$, in terms of d, Δd, and Σ.

    (c) (4 points) With some assumptions, we can make the approximation $\Delta d \approx 2\sqrt{3} \cdot d\,(M_p/3M_{\rm s})^{1/3}$. Set $M_{\rm p} = M_{\rm iso} = M_{\rm feed}$ and substitute our expression for Δd from the previous part to derive $M_{\rm iso}$ as a function of $M_{\rm s}$, d, Σ, and dimensionless constants. You do not need to simplify all the dimensionless constants; you can just lump them into one big constant C if you want. I mainly care about how $M_{\rm iso}$ scales with $M_{\rm s}$, d, and Σ.

    (d) (4 points) Briefly explain what the frost line is. Explain why crossing the frost line increases the surface density of solids and accelerates core growth.

40. (30 points) Directly imaging a planet is extremely difficult. Consider a system containing a planet of radius R_p and Bond albedo α orbiting a star of luminosity L_s at a distance d from the star. Assume the planet emits no energy of its own; instead, its luminosity comes entirely from reflecting the star's light.
   (a) (3 points) What is the flux of light incident on the planet at a distance d from the star?
   (b) (3 points) What is the luminosity of the planet due to reflected light?
   (c) (4 points) Suppose that we're interested in finding a Jupiter-like planet around a Sun-like star. Estimate, to the nearest few orders of magnitude, $L_\mathrm{p}/L_\mathrm{s}$, the ratio of the luminosity (from reflected light) of our Jupiter-like planet to the luminosity of our Sun-like star. Jupiter has a radius of 7×10^7 meters and orbits 8×10^{11} meters (about 5 AU) away from the Sun.

   When we observe stars, they have a point spread function (PSF) where brightness decreases gradually from the center. To detect a planet, the number of photons (i.e., the signal) from the planet must exceed the noise from the host star's PSF at the planet's location. For the purpose of this question, let $S_\mathrm{s}(\theta)$ be the signal (number of photons) from star at angular distance θ, $N_\mathrm{s}(\theta) = \sqrt{S_\mathrm{s}(\theta)}$ be the noise from star at angular distance θ, and S_p be the signal (number of photons) from planet.



   (d) (2 points) If our Sun-Jupiter analogue was 5 parsecs away, then the star and planet would have an angular separation of 1 arcsecond. The image above shows how the intensity of light from a star observed by Hubble falls with distance from the center. By what factor does the intensity of the star's light decrease when you go from $\theta = 0$ arcseconds (the center) to $\theta = 1$ arcsecond?
   (e) (2 points) At $\theta = 1$ arcsecond, what is the noise level relative to the star's central intensity?
   (f) (4 points) Using your answers from parts (c) and (e), explain why it is pretty difficult to take an image of a planet based on its reflected light.
   (g) (6 points) Scientists employ several strategies to overcome these challenges. Briefly explain (i) why planets are often easier to directly image in infrared than visible light and (ii) what coronagraphs and adaptive optics are, and how each helps with direct imaging.
   (h) (6 points) All in all, direct imaging is most successful at finding planets that are young, massive, and far from their parent stars. Briefly explain why.

41. *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.