Science Olympiad
Solar System
UT Regional 2022

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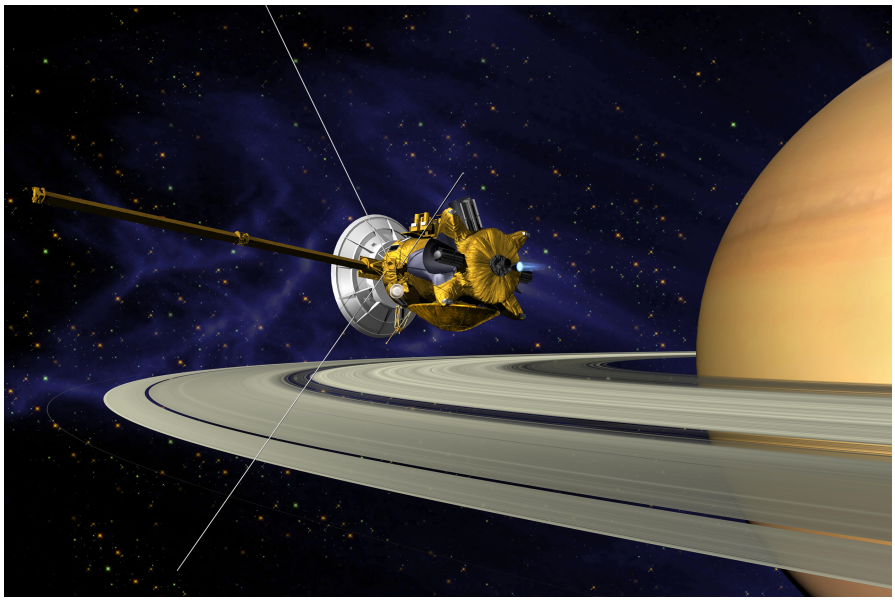
Austin, Texas



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.
- There is no penalty for wrong answers.
- Above all else, just believe!

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Section A [40 points]

Determine whether the following statements are true or false. [20 points]

1. ___ The Sun is at the center of the Solar System.
2. ___ Saturn, Uranus, and Neptune are all beyond the Asteroid Belt.
3. ___ Planets farther from the Sun move faster than those closer to the Sun.
4. ___ Kepler-138b is the closest exoplanet to the Solar System.
5. ___ The two primary constituent gases in Saturn's atmosphere are hydrogen and helium.
6. ___ Due to its unique axial tilt, each pole on Uranus alternates between 42 years of sunlight or darkness.
7. ___ Iapetus is the most geologically active Galilean moon.
8. ___ Pluto is a Trans-Neptunian Object.
9. ___ Triton, Arrokoth, and Io are all natural satellites of Solar System objects.
10. ___ Saturn is closer to the Sun than Jupiter.
11. ___ The Kepler space telescope searches for exoplanets through the transit method.
12. ___ The ALMA telescope is the largest observatory ever put into orbit.
13. ___ The *Magellan* mission ended by burning up in the atmosphere of the planet it was studying.
14. ___ HL Tauri is notable for contradicting previous models for how quickly planetary systems develop.
15. ___ Pluto is the farthest object ever visited by a spacecraft.
16. ___ When an object is moving towards us, the light it emits is "blueshifted".
17. ___ The primary component of Venus's atmosphere is carbon dioxide.
18. ___ Uranus gets its blue-green color from the presence of water ice in its atmosphere.
19. ___ Radial velocity data can help astronomers estimate the eccentricity of a planet's orbit.
20. ___ On extraterrestrial bodies, the word "planitia" is used to describe flat, low-lying surface features.

Complete the following statements with the name of an object or mission from the rules. No object or mission will be used more than once. [20 points]

21. _____ remains the only probe to visit all four of the outer planets in a single mission.
22. The planets in the _____ system were discovered through direct imaging.
23. The most massive "Ice Giant" in the Solar System is _____.
24. _____ is the largest moon around Neptune.
25. _____ is the hottest planet in the Solar System.
26. In 1930, Clyde Tombaugh discovered _____.
27. Volcanism on _____ is due to tidal heating from Jupiter and other moons.
28. _____ is known for its distinctive equatorial ridge.
29. The planets in the TOI-561 system were discovered using _____.
30. The most massive planet in the Solar System is _____.

Section B [72 points]

Use the attached Image Set for Section B in this section.

31. (2 points) Order the objects shown in the following images by *their distance from the Sun*, from closest to farthest: 2, 3, 4, 12, and 18.

32. (2 points) Order the objects shown in the following images by their *mass*, from least massive to most massive: 1, 3, 6, 11, 15.

33. Image 1 depicts the internal structure of a terrestrial planet with a diameter approximately equal to Earth's.
    (a) (1 point) What planet is shown in this image?
    (b) (1 point) How many natural satellites orbit this planet?
    (c) (1 point) Which image shows the surface of this object?
    (d) (2 points) What layers of this object's internal structure are denoted by the letters "A" and "B"?
    (e) (1 point) What is the primary composition of layer "A"?
        A. Carbon dioxide
        B. Sulfuric acid
        C. Iron oxide
        D. Rocky compounds
    (f) (1 point) What is the primary composition of layer "B"?
        A. Hydrogen
        B. Silicate compounds
        C. Sulfur dioxide
        D. Iron and nickel

34. Iapetus is one of the largest natural satellites of the planet Saturn.
    (a) (1 point) Which image shows Iapetus?
    (b) (1 point) What spacecraft or telescope took this image?
    (c) (1 point) What instrument on this spacecraft or telescope collected the data to make this image?
    (d) (1 point) This mission carried a secondary probe for exploring a different natural satellite of Saturn, Titan. What was the name of this probe?
    (e) (1 point) What major region of Iapetus is prominently depicted in this image?

35. All of the gaseous planets in our Solar System have rings, but all ring systems are not created equal.
    (a) (1 point) The ring system of which planet is shown in Image 12?
    (b) (1 point) What are these rings mostly made out of?
    (c) (1 point) Which image shows the spacecraft that took this image?

36. Triton is one of the largest moons in the Solar System and has very interesting geological properties.
    (a) (1 point) Which image shows the surface of Triton?
    (b) (1 point) The terrain in this image has a special name. What is it?
    (c) (2 points) What do astronomers believe causes the terrain mentioned in part (b)?

37. The Kepler Space Telescope began a new mission plan called "Second Light" in 2013, as a follow-up to its previous observations using its remaining capabilities.
    (a) (1 point) What abbreviation is used for stars observed during this "Second Light" mission?

(b) (2 points) The "Second Light" mission was a "new lease on life" for Kepler, which had been experiencing some mechanical difficulties before. What were these problems, and why would they have prevented Kepler from observing objects like it normally did?

(c) (1 point) The "Second Light" mission discovered the youngest exoplanet on this year's rules manual. What is its name?

(d) (3 points) Which planet in our Solar System is this exoplanet most similar to in terms of size? Distance from parent star? Surface temperature?

38. Image 2 depicts a composite image of an object on the rules manual.

(a) (1 point) What object is shown in this image?

(b) (1 point) What do the four labeled circles indicate?

(c) (2 points) Why is this image unique, as far as objects of this type go?

39. Image 4 depicts a Solar System object in false color.

(a) (1 point) What is the name of this object?

(b) (1 point) Which mission captured this image?

(c) (2 points) What is the current location and communication status of this mission?

(d) (1 point) What do astronomers believe the bright, white feature in this image is?

(e) (2 points) Why does the limb of this object look red?

40. Arrokoth is a distant Solar System object.

(a) (1 point) What image shows this object?

(b) (1 point) Which mission is responsible for capturing this image?

(c) (1 point) Which image shows an artist's interpretation of the spacecraft from part (b)?

(d) (1 point) Which of the following is **not** a current or prior designation for this object?

A. Ultima Thule
B. KBO 1110113Y
C. 2014 MU69
D. Cubewano 1

(e) (1 point) Which of the following categories does this object **not** fall under?

A. Trans-Neptunian Object
B. Trojan
C. Classical KBO
D. Planetesimal

(f) (2 points) Before the mission in part (b) flew by this object, astronomers constrained the shape of Arrokoth through occultations. In your own words, explain what an occultation is and how astronomers could use them to create a concept of what Arrokoth may look like.

41. *Galileo* was an American deep space mission to explore Solar System bodies.

(a) (1 point) Which image shows an artist's interpretation of *Galileo*?

(b) (1 point) Of the objects on the rules manual, which were directly studied by *Galileo*?

(c) (2 points) There are two images on the Image Sheet that were taken by *Galileo*. Which ones are they?

(d) (2 points) *Galileo* produced electricity using a radioisotope thermometric generator (RTG). Why did it not use solar panels?

(e) (2 points) How did this mission end? Why did it conclude in this way?

42. Sputnik Planitia is a prominent surface feature with a diverse geology.
    (a) (1 point) Which image shows this feature?
    (b) (1 point) Which object is this feature on?
    (c) (1 point) Sputnik Planitia constitutes about one-half of what other major surface feature?
    (d) (1 point) Which of the following is the primary chemical constituent of Sputnik Planitia?
        A. Nitrogen ice
        B. Rocky silicates
        C. Methane ice
        D. Water ice

43. In 2018, NASA launched a two-year mission to detect exoplanets around the brightest near-Earth stars.
    (a) (1 point) What is the full name of this mission?
    (b) (1 point) Which image shows an artist's interpretation of this mission?
    (c) (3 points) What types of planets is this method best at detecting? Provide at least three characteristics of such planets.
    (d) (5 points) Let's imagine two identical planets. Both are the same size and have the same equilibrium temperature, but Planet A is around a Sun-like star, while Planet B is around a red dwarf, which is much smaller and cooler. Would it be easier to detect the presence of special compounds (e.g., water, ozone, methane, etc.) in the atmosphere of Planet A or B? In other words, does the benefit of larger transit depth and shorter orbital period for Planet B outweigh the lower signal to noise from the lowered brightness of its parent star?

44. Pele is a massive volcano on the surface of an object in the Solar System.
    (a) (1 point) On which object is Pele found?
    (b) (1 point) Which image shows this object?
    (c) (3 points) Pele is well known for an archetypal feature that it produces through sulfur degassing from erupting lava. What type of feature is this, and how does it affect the surrounding geology of Pele? What other visible feature in the image is evidence of this effect?

Section C [40 points]

Use the attached Image Set for Section C in this section.

45. The planet Uranus has a relatively little-known structure and composition, due to the lack of missions to visit it directly. The plot given in Image A summarizes current knowledge about one aspect of the planet's composition.
    (a) (1 point) What portion (surface, atmosphere, or interior structure) of Uranus is described by the plot shown in Image A?
    (b) (8 points) Briefly describe what physical characteristics are being plotted and their relationship to one another. You should discuss at least three different physical quantities.
    (c) (4 points) What does the location of clouds of differing composition on this plot imply about the necessary conditions of their formation? Relate these to altitude as in the question above, and compare H_2O and CH_4 in this respect.
    (d) (3 points) Which two major gases in Uranus's composition are absent from the clouds in this plot? Why are they absent?

46. Kepler's Laws are used by astronomers to describe the motion and structure of planetary systems, often as they orbit their parent star, but can also be applied in the context of moons or even two stars in a binary. Image B depicts an application of Kepler's Laws in a hypothetical star-planet system.
    (a) (3 points) What physical values do a, b, and T represent in Image B?
    (b) (1 point) What would you expect to happen to T if a were doubled?
    (c) (1 point) Qualitatively, what would happen to the eccentricity of the orbit (i.e., how "oval-shaped" the orbit is) if a were increased while b was held constant?
    (d) (2 points) At which positions around the star would the planet be travelling the fastest and slowest?
    (e) (3 points) How is the rate of change of θ related to the orbital speed of the planet? How can you express your answer to part (d) in terms of the rate of change of θ?

47. Terrestrial planet formation is thought to occur through collisions of solid objects. When two initially solid objects collide, their outcomes can be divided broadly into three categories, as shown in Image C:

    - **Accretion.** All or most of the mass of the impactor becomes part of the mass of the final body, which remains solid. Small fragments may be ejected, but overall there is net growth.
    - **Fragmentation + reaccretion (shattering).** The target body breaks into many pieces, but they come back together. It may look like a rubble pile.
    - **Dispersal.** The impact fragments the target into two or more pieces that do not remain bound.

    Consider an extremely basic model in which an impactor of mass m collides with a larger object of mass M (the "impacted" object) at a velocity v. The specific energy of the impact would then be

    $$Q \equiv \frac{mv^2}{2M}$$

    (a) (3 points) Does it require a higher specific energy to disperse or shatter the impacted object? Why?

    Image D shows how Q_D^*, the minimum specific energy to disperse an object, varies with the size of the impacted object.

    (b) (6 points) When the impacted object is very small, it is actually easier to disperse larger objects! Why would this be the case?
    (c) (6 points) After a certain point, Q_D^* begins to increase with the size of the impacted object, as gravitational forces dominate. Why would this be the case?