Science Olympiad

Purdue Invitational

January 31st, 2026

Solar System B Key

Directions:

- Each team will be given 50 minutes to complete this exam
- Section A (MCQ/Fill-In), Section B (Short Answer). Section C (Astrophysics)
- Use 2-3 decimal places in final answers for Section C, partial credit will be given for work

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Name(s): _____ Team #: B___

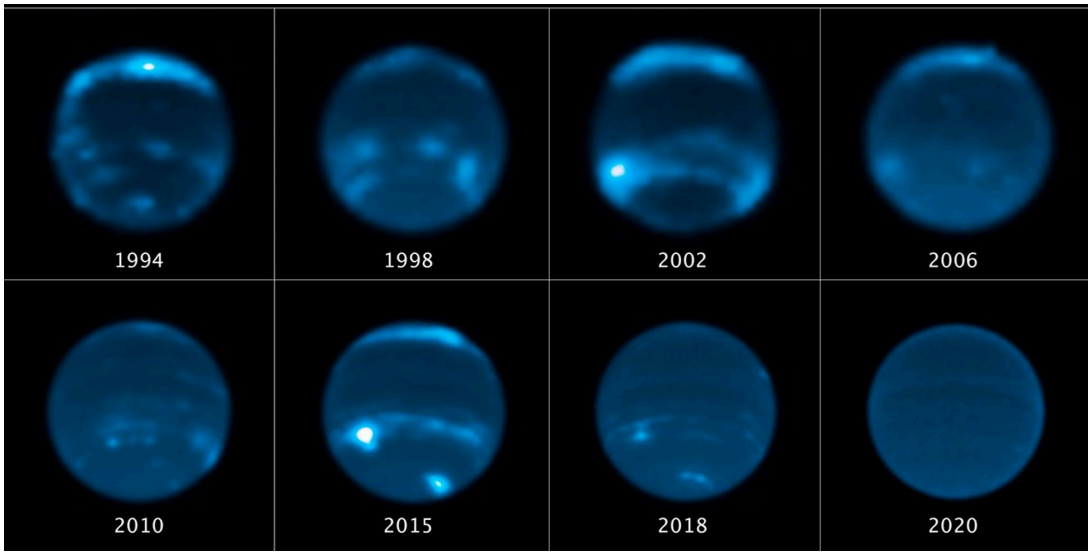
Section A: MCQ/Fill-In (27 Points)

(1 pt unless otherwise specified)

1. Why does Mercury experience such extreme temperature variations between day and night?
    a. It has no magnetic field.
    b. It rotates too slowly or too quickly.
    c. It does not have a substantial atmosphere.
    d. It reflects too much sunlight.
2. Which spacecraft was the first to orbit Mercury?
    a. BepiColombo
    b. MESSENGER
    c. Mariner 10
    d. Galileo
3. What is unusual about Mercury's rotation compared to its orbit?
    a. It rotates at the same speed as Earth.
    b. It rotates once for every orbit around the sun.
    c. It rotates three times for every two orbits around the sun.
    d. It does not rotate at all.
4. Which element makes up most of Mercury's core?
    a. Iron
    b. Nickel
    c. Silicon
    d. Carbon
5. What is the Caloris Basin on Mercury?
    a. A huge canyon formed by erosion
    b. A region of volcanic plains
    c. A giant impact crater
    d. A chain of mountains
6. What gives Saturn its distinctive ring system?
    a. Ice and rock particles orbiting the planet
    b. Solid bands of rock and dust
    c. Gas clouds held by magnetism
    d. Frozen methane sheets
7. What causes Saturn's rings to appear bright?
    a. They emit their own light.
    b. They reflect sunlight.
    c. They are made of glowing gas.
    d. They are covered in volcanic dust.

8. What generates Saturn's magnetic field?
    a. Liquid metallic hydrogen inside the planet
    b. Rotating ice particles in its rings
    c. Electrical storms on its surface
    d. The gravitational pull of its moons
9. What gives Saturn's rings their structure and gaps?
    a. Collisions with comets
    b. Magnetic fields
    c. Gravitational interactions with moons
    d. Solar wind pressure
10. What causes Saturn to have a flattened shape at its poles?
    a. Its high temperature
    b. Its rapid rotation
    c. Tidal forces from the sun
    d. Gravitational pull from its moons
11. What type of star is HD 209458?
    a. Red dwarf
    b. G-type main-sequence star
    c. White dwarf
    d. F-type supergiant
12. HD 209458 b was the first exoplanet observed to:
    a. Orbit two stars
    b. Have an atmosphere directly detected
    c. Be discovered using the radial velocity method
    d. Show signs of habitability
13. What is the approximate distance from Earth to HD 209458?
    a. 10 light years
    b. 50 light years
    c. 150 light years
    d. 600 light years
14. What is the orbital period of HD 209458 b?
    a. About 1.2 Earth days
    b. About 3.5 Earth days
    c. About 10 Earth days
    d. About 30 Earth days

15. HD 209458 b is classified as what type of exoplanet?
    a. Mini-Neptune
    b. Super-Earth
    c. Hot Jupiter
    d. Ice giant
16. What Object is pictured in this image set?

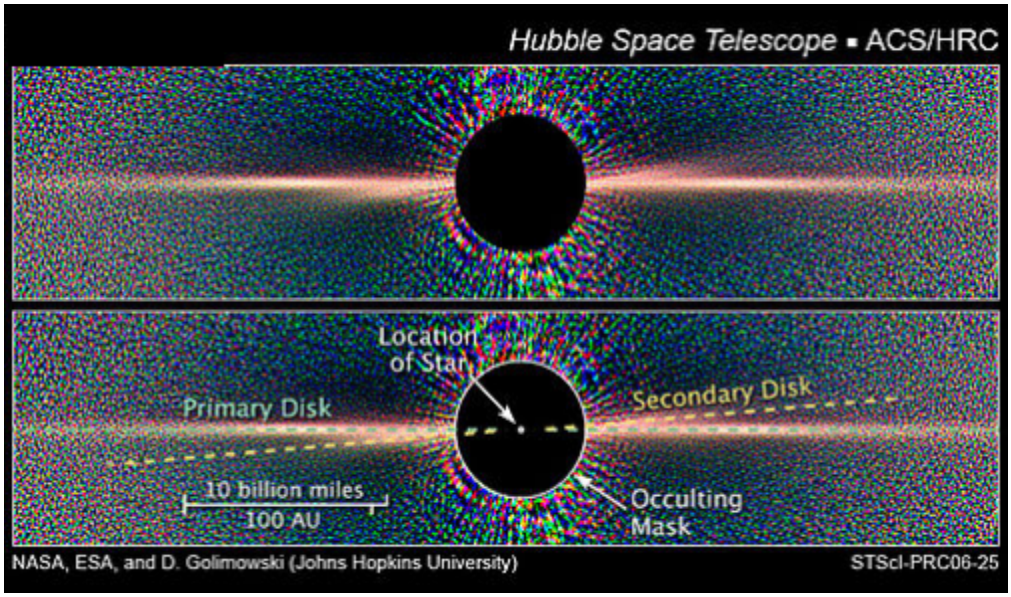


    a. Saturn
    b. Neptune
    c. Jupiter
    d. Pluto
    e. Uranus
17. What is the largest object in the asteroid belt?
    a. Ceres
    b. Armageddon
    c. Triton
    d. 25143 Itokawa
    e. Asteriodia Major

18. Which image shows 25143 Itokawa?

19. 25143 Itokawa was discovered in what year?
    a. 1899
    b. 1998
    c. 1988
    d. 1997

20. What object is shown in this picture?

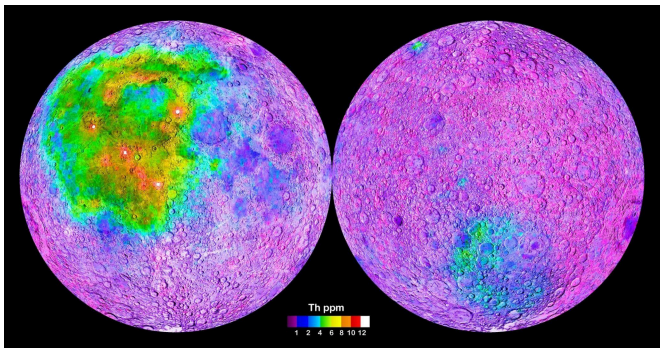


    a. HL Tauri
    b. Uranus
    c. Beta Pictoris
    d. HD 209458
    e. This is not one of the objects we studied

21. Beta Pictorioris is relatively:_____ (Chose all that apply)
    a. Dim
    b. Bright
    c. Young
    d. Old
    e. Sigma
22. Many scientists believe that Pluto is **differentiated**, like Earth, meaning that it has layers such as a core, mantle, and crust. Heat is necessary for a planet to become differentiated because it causes materials with different properties to separate. Which of the following is a likely heat source that allowed Pluto to become differentiated?
    a. Sunlight
    b. A giant impact
    c. Radioactive decay
    d. Tidal forces between Pluto and Charon

The Sputnik Planitia on Pluto displays many polygonal shapes, like those in the image below. Questions 23 and 24 will be about these polygons.

23. Tundra regions on Earth display polygonal patterns, which form as the result of ice and freeze-thaw cycles. The polygon patterns on Pluto are formed by a similar process.
    a. True
    b. False
24. What process is believed to form the polygons of Sputnik Planitia?
    a. Freeze-thaw cycles
    b. Convection of ice
    c. Fracturing as the surface cools
    d. Both A and B
    e. Both B and C
25. The following map depicts Thorium concentrations on the Moon. A higher Thorium concentration is associated with the presence of KREEP materials. KREEP materials become concentrated as magma cools in a process called:
    a. Crystal formation
    b. Mantle cooling
    c. Magma separation
    d. Crystal fractionation



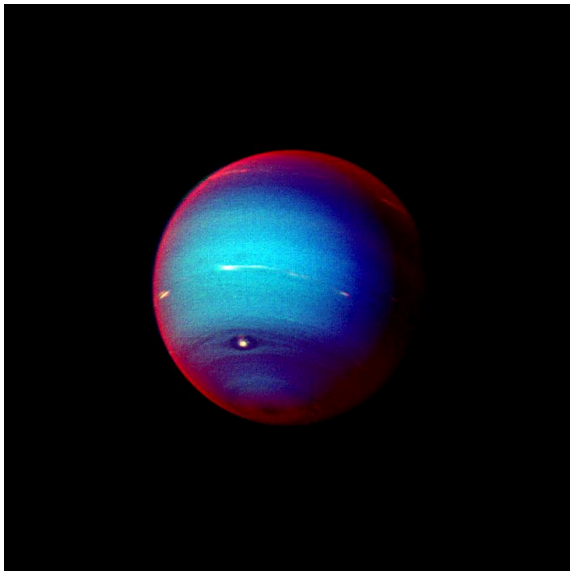
26. One of the main goals of the Lunar Reconnaissance Orbiter mission was to create a 3D map of the Moon's surface. According to NASA, two of the main uses of the map would be: (select two answers!)
    Give 0.5 points for correctly selecting one of the answers.
    a. To identify future landing sites.
    b. To observe the far side of the Moon.
    c. To discover new topographical features.
    d. To locate potential resources.
27. The LRO spacecraft has an instrument called the Lunar Orbiting Laser Altimeter. The data collected from this instrument allows for a topographic model of the lunar surface to be created. The method by which this instrument collects data about the Moon's surface is similar to:
    a. Sonar detection
    b. Radar detection
    c. The Doppler Effect
    d. Both A and B
    e. Both B and C
    f. All of the above

Section B: Short Answer (17 Points)

(0.5 pt unless otherwise specified)

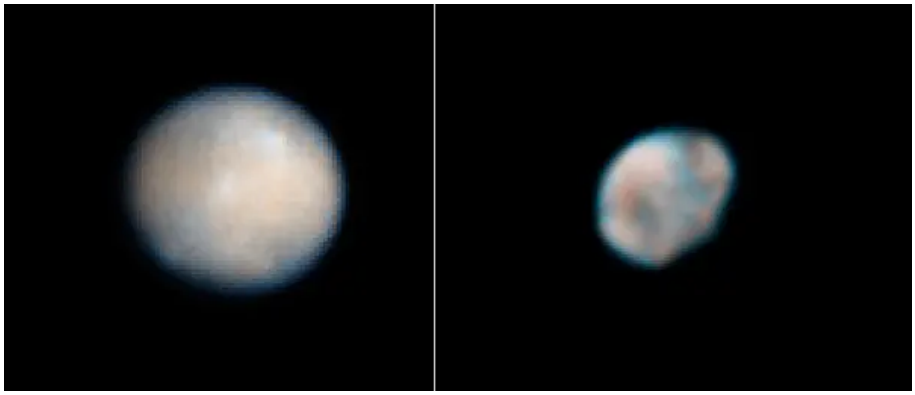
1. What is the protoplanetary disk and why is it important in planet formation?
2. Describe the process of accretion in planet formation.
3. What is the difference between terrestrial and gas giant planets in terms of formation?
4. Explain how planetesimals form from dust grains in a protoplanetary disk.
5. How do collisions and impacts influence the evolution of planets?
6. List the following characteristics of 51 Pegasi
    a. Evolution Stage:_____*Main Sequance*
    b. Apparent Magnitude:_____*5.4-5.5*
    c. Distance:_____*50.6-50.7 ly or 15.5 pc*
    d. Mass:_____ *1.0-1.1 MoS*
    e. Radius:_____*1.1-1.2 RoS*
    f. Luminosity:_____ *1.3-1.4 LoS*

7. List the approximate Radius of this object.



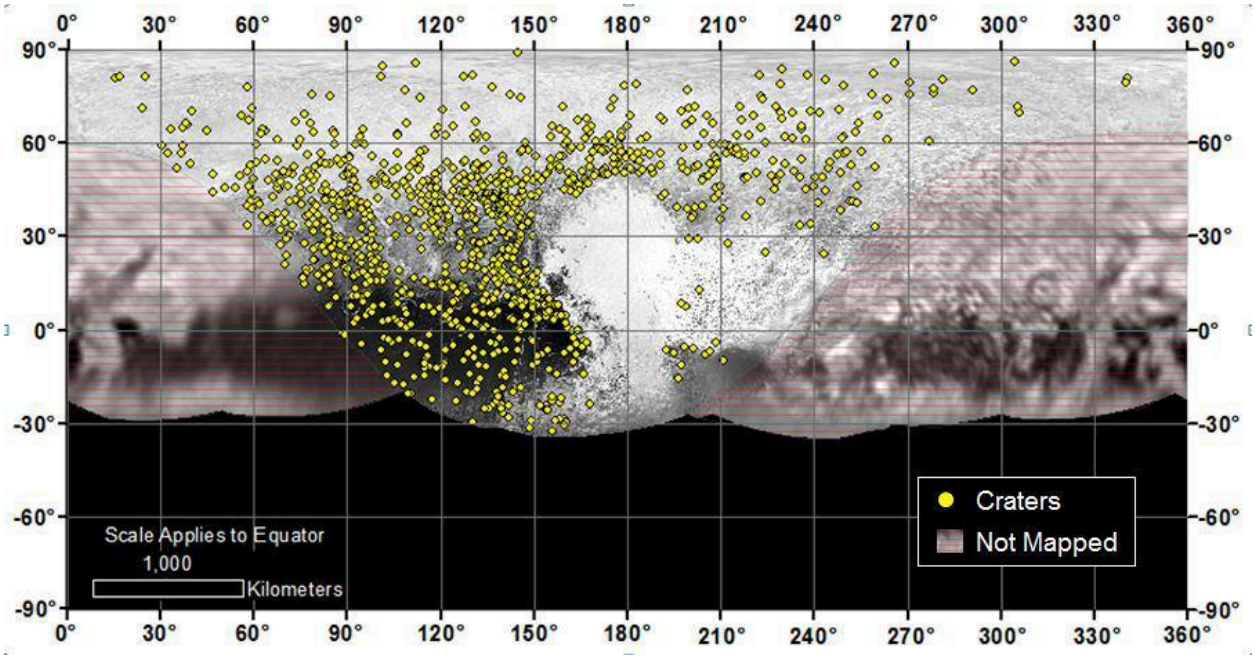
    a. *24k-25k kilometers, 15k-16k miles, 3.9 Earth radii, 0.3444 Jupiter radii all acceptable answers*

8. Identify this object.



a. Ceres

9.



The map above shows the distribution of craters on Pluto's surface. Notice the central area that does not have as many craters. What is the name of this region? What does the lack of craters tell you about the surface in that region compared to the rest of the planet? Your answer should be 2-4 sentences.

Point breakdown: 1 point for correctly naming the region. 3 points for correctly explaining the implications of the crater distribution.

Correct name: Sputnik Planitia

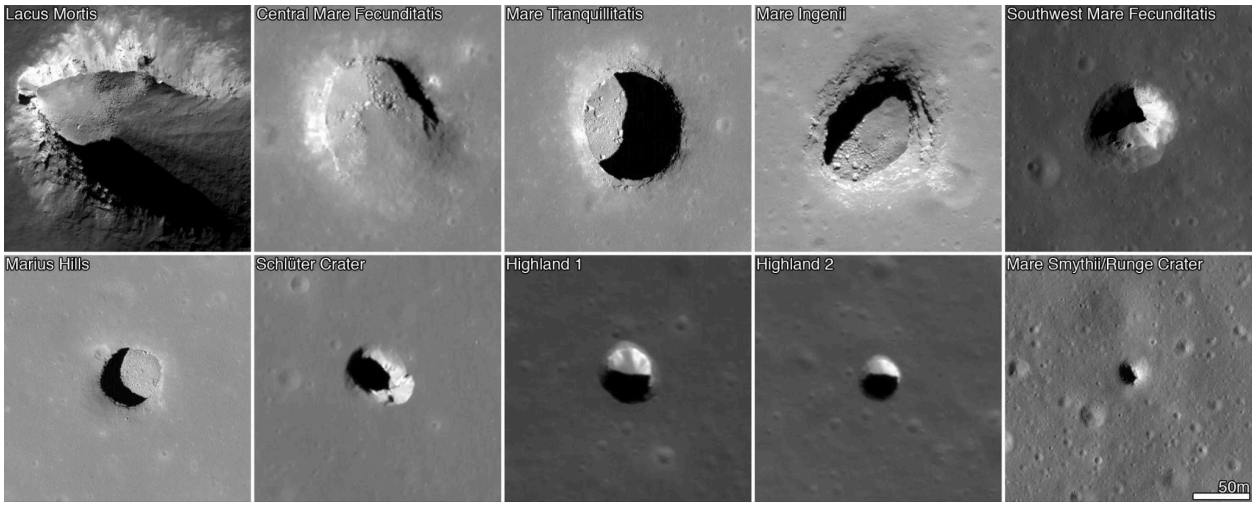
Short answer should boil down to "fewer craters = younger surface, active geologic processes". 1 point for stating that the surface is likely younger, 1 point for mentioning active processes shaping the surface, and 1 point for having proper grammar/complete sentences/etc.

10. The image below is a collage of images taken by the LRO, depicting possible cave entrances on the Moon. The cave entrances have interesting characteristics that can reveal information about their formation. Study the images and write 1-2 sentences for each characteristic listed below, describing what you can conclude. (6 pts total, 2 pts for each feature)

No rim around the crater - *indicates that the pit was not formed by an impact, but by collapse of surface material. 1 pt for mentioning no impact, 1 pt for mentioning collapse as formation mechanism.*

Located in mare - *The Mare are basaltic plains formed by the cooling of lava. The fact that the pits are located in the Mare implies that they are also associated with volcanic activity/cooling of lava. 1 pt for mentioning Mare association with volcanic activity/lava. 1 pt for suggesting that the pits/caves are also associated with lava.*

Deep shadows - *Indicates that there is overhang and/or an extended cavern associated with the opening. 1 pt for mentioning overhang/something casting the shadow. 1 pt for stating that the shadows could indicate access to the greater cave system.*



Section C: Astrophysics (17 Points)

1) **Jupiter Shrinkage (9 pts total).** Jupiter is the largest giant in the Solar System, and accounts for ~70% of planetary mass in the solar system. An odd feature of Jupiter is that it appears to radiate more energy than it receives from the Sun. The following questions will deal with this scenario.

   a) (2 pts) How is Jupiter able to radiate away more energy than it receives?

   Kelvin-Helmholtz Mechanism, gravitational contraction produces heat/energy which is then radiated away

To analytically solve this problem, start with the equation for gravitational potential energy between two point masses: $U = -\frac{Gm_1m_2}{r^2}$. Assume that the Jupiter is a perfect sphere with uniform density ρ.

   b) (2 pts) What is the function $m(r)$ (mass enclosed under a radius r)? (2 pts)

   $m(r) = \frac{4}{3}\pi r^3 \rho$

Through some calculus and virial theorem, we get the equation for the gravitational potential energy of a sphere

$$|U| = \frac{3GM^2}{10R}$$

   c) (3 pts) What is the formula for the maximum amount of time spent on the Kelvin-Helmholtz Mechanism for a star of luminosity L?

$$t = \frac{Energy}{Luminosity} = \frac{3GM_J^2}{10R_J}/L_\odot$$

+3 point for dividing formula given above by luminosity

d) (2 pts) Would you expect the rate at which Jupiter shrinks to be higher or lower in the past billion years?

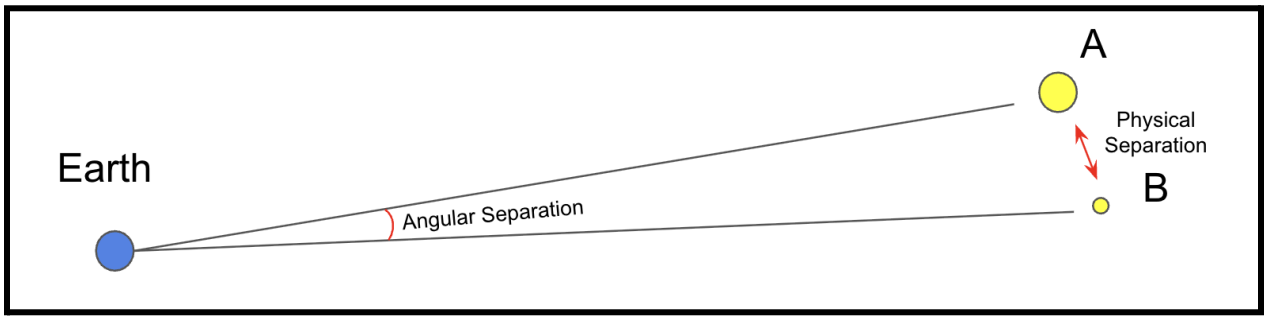
Higher. Because Jupiter was at a higher temperature in the early Solar System, the rate at which Jupiter cools is proportional to its internal energy, which was greater in the past

+1 point for stating it would be higher
+1 point for appropriate reason

2. Double Dwarf (8 pts total). The Pluto-Charon system is unique because of the relatively large mass of the moon, Charon, compared to the larger body.

a) (2 pts) How can angular distance be used to determine the masses of celestial bodies?

If the distance to the celestial bodies is known, the angular distance can be used to find the physical distance, which can be utilized in Kepler's Third Law to determine the mass of the system.



+1 point for relating angular distance and physical distance
+1 point for mentioning Kepler's Third Law

b) (3 pts) The Earth's mass if around $5.94 \cdot 10^{24}\ kg$. What is the order of magnitude mass of the Pluto-Charon system??

$$m_{total} = 10^{22}\ kg$$

+2 point for correct order of magnitude(any version)
+1 point for units

c) (3 pts) The formula for a circular orbit is $v = \sqrt{\frac{Gm_{total}}{r}}$. What is the order of magnitude of the relative velocity of Pluto and Charon in km/s? Assume $G = 10^{-11}\ Nm^2kg^{-2}$ and $r = 10^4\ km$

$$v = \sqrt{\frac{Gm_{total}}{r}} = \sqrt{\frac{(10^{-11})(10^{22}\ kg)}{(10^7\ m)}} \Rightarrow 10^{-2}\ km/s$$

+1 point for using circular orbital velocity formula
+1 point for correct unit conversions
+1 point for final answer