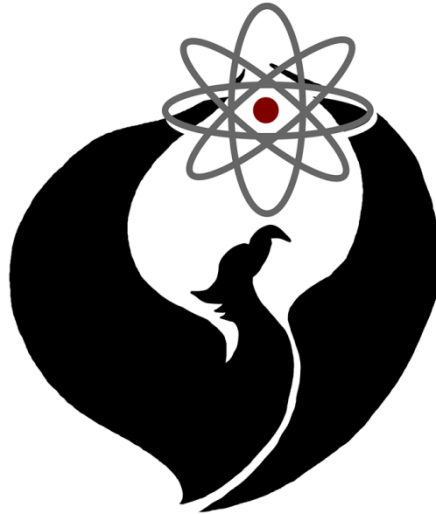


Solar System B



University of Chicago Science Olympiad

Division B Invitational 2019

Saturday, February 23, 2019

Team Name: _____

Team Number: _____

Instructions:

0. Don't start until told!
1. Write all your final answers on the answer sheet for points.
2. Ask if a question is unclear
3. Have fun!

I. “Written Test” Portion [43 points]

1. [2 pts] Which two of the following are reasonable hypotheses as to how the Oort cloud was formed? (Choose 2)

- A. Many planet-sized objects getting fractured into small pieces
- B. The Sun capturing objects from outside the current solar system
- C. Small objects getting scattered into outer regions of the solar system
- D. Volcanic matter from rocky planets hardened in space as particles drifted outward
- E. Some members of the asteroid belt went on strike and moved to the outskirts of the solar system

2. [1 pt] A leading theory on planetary formation is the core accretion model. It says that small particles in the protoplanetary disk clump together to form planetesimals, onto which other particles can accrete relatively quickly. What’s the major drawback of this model?

- A. Rocky planets that form close to the sun are made of particles that are too solid to stick to each other and allow for growth.
- B. Gas giants would experience runaway growth that’s too fast under this model.
- C. The model has trouble explaining how centimeter- and meter-sized objects can accumulate into much larger (~1 km) objects other since they have weaker gravitational.
- D. As planetesimals grow, it’s unclear how their growth would slow given their increasing mass and gravitational attraction.

3. [1 pt] What shape is Ceres?

- A. Spherical (equal radius in each axis)
- B. Oblate spheroid (flattened in one axis – like a fluffy pancake)
- C. Prolate spheroid (longer on one axis – like an egg but symmetric)
- D. Irregular ellipsoid (different length on each axis)
- E. Doughnut (wow that sounds tasty since Ceres is the Goddess of grain)

4. [1 pt] The interior of Ceres is thought to have a rocky core surrounded by an icy mantle. What is interesting about this?

- A. The differentiated interior suggests Ceres was once geologically active.
- B. The separation of materials suggests that Ceres was made from a large rocky body colliding with a large icy body.
- C. It's rare to find dwarf planets with water ice (as opposed to ammonia ice).
- D. Highly oblate objects don't usually have such layers.
- E. The frozen state of the ice suggests that Ceres is colder than other dwarf planets.

5. [1 pt] What happened in November 2010 that allowed astronomers to estimate the size of Eris?

- A. The Earth cast a shadow on Eris.
- B. New Horizons performed a flyby and sent back pictures.
- C. Eris passed in front of a dim star.
- D. Astronomers finished crunching numbers from previously recorded light curves.
- E. NASA pointed the Kepler space telescope at Eris.

6. [1 pt] What about Haumea's surface composition allows it to be quite reflective? (People think it reflects over half the light that hits it (albedo > 0.5))

- A. It is metallic.
- B. It has a thin layer of ice.
- C. There's a layer of glass in front of rock forming a sort of mirror.
- D. It has many shiny silicate minerals.
- E. Nothing in particular – it's just close to us so it looks bright.

7. [1 pt] What is responsible for the fact that we always see the same side of the moon?

- A. Lunar cycles B. Tidal locking C. Rotational resonance
- D. The near side is heavier E. Gravitational effects of tides on Earth

8. [1 pt] What is believed to be the primary component in the moon's core?

- A. Iron B. Magnesium C. Silicon D. Uranium E. Hydrogen

9. [1 pt] Which planet is Mimas a moon of?

(Free response)

10. [4 pts] Which of the following geological features are officially recognized as being on Mimas? (select all that apply)

A. Canyons B. Chasms C. Colles D. Crater Chains E. Craters

11. [1 pt] What does Mimas's mean density of 1.15 g / cm^3 suggest about its chemical composition?

(Free Response - just put a couple words)

12. [1+1=2 pts] Which planets is the asteroid belt located between? (Write the closest planets)

(Free Response)

13. [2 pts] How thick is the asteroid belt in Astronomical Units (AU)?

(Free Response)

14. [1 pt] What is the second largest object in the asteroid belt?

A. Pallas B. Vesta C. Ceres D. Hygiea E. Hydra

15. [(1+2)x3=9 pts] What are the three common types of asteroids by composition? Also indicate what the type name stands for. Also write in descending order of prevalence.

(Semi-Free Response)

16. [1 pt] Which of these is significantly less reflective than the others and consequently harder to observe?

17. [1 pt] What property of Trojans' orbits allows them to follow a steady path?

A. Resonance B. Cadence C. Tidal effects D. Consonance
E. Gravitational instability

18. [1 pt] At which Lagrange points of a larger object can you find Trojans? (Select all that apply)

A. L1 B. L2 C. L3 D. L4 E. L5

19. [1 pt] What angle(s) are these from the larger object? (angle with respect to the sun)

A. 0° B. 45° C. 60° D. 90° E. 180°

20. [1 pt] What's (on the order of) a typical dynamical lifetime of a Centaur's orbit?

A. 5×10^4 years B. 5×10^5 years C. 5×10^6 years

D. 5×10^7 years E. 5×10^8 years

21. [1 pt] This is relatively short compared to the lifetime of the sun ($\sim 10^{10}$ years). What makes Centaurs' orbits unstable?

A. Centaurs are weakly held together and can easily fall apart.

B. They start orbiting around each other after that point.

C. Highly elliptical orbits bring them close to the Sun, so they are likely to get disrupted by the asteroid belt.

D. Their rotations have a wobble that grows until it has an appreciable effect on the orbit.

E. Their orbits are likely to get disrupted by bigger planets like Saturn or Neptune.

22. [1 pt] It can be hard to photograph Centaurs (and other small objects in our solar system) from close, so astronomers often look at objects' spectra. What information can we learn about a Centaur from its spectrum?

A. Chemical composition B. Shape C. Temperature D. Distance from us

E. Orbital behavior (orbital period, eccentricity, etc.)

23. [2 pts] When was Oumuamua discovered?

(Free Response - Give month and year)

24. [4 pts] Which of the following are true of Oumuamua's motion? (select all that apply)

A. It is tumbling (irregular rotation).

B. Its rotation rate is comparable to an asteroid.

C. It has a very long orbital period.

D. Follows a parabolic path with the sun at a focus.

E. Its closest approach to the sun was closer than Venus.

25. [1 pt] How did astronomers determine the shape of Oumuamua?

- A. Direct Imaging
- B. Inferred from light curves
- C. Looking at the redshift of reflected sunlight
- D. Its silhouette as it passed in front of the sun
- E. Its chemical composition suggests a non-radially symmetric shape

II. “Hands-On / Interpretive Task” which is also kind of a written test [24 points]

26. Kepler’s 3rd Law:

$$P^2 \propto r^3 \text{ (for fixed system mass)}$$

How much farther would the moon need to increase its orbital period from one lunar month to one calendar month? We’re interested in the ratio of this new distance r_{cal} to the moon’s current radius: $r_{\text{cal}}/r_{\text{moon}}$.

a. [5 pts] Write $r_{\text{cal}}/r_{\text{moon}}$ in terms of P_{lun} (lunar month in days) and P_{cal} (calendar month in days).

(Free response)

b. [2 pts] Plug in $P_{\text{lun}} = 27$ days and $P_{\text{cal}} = 30$ days but don’t compute (too much effort to do by hand!). How does $P_{\text{cal}}/P_{\text{lun}}$ compare to $r_{\text{cal}}/r_{\text{moon}}$? Is it less than, more than, or equal?

(Free response - rewrite the equation and also circle an option)

c. [1 pt] Is this relation true in general for any P_{lun} that is greater than P_{cal} ?

(Yes/No)

Mission Identification time!

On the picture sheet, there are four images. (a) Identify the object in each image, (b) write down the mission it is most likely to have come from, and (c) say when the picture was taken (within 5 years is good enough for full credit).

Hint 1: Lucy has not yet launched and therefore couldn’t have taken any of these photos.

27. [1+1+2=4 pts] Image 1

28. [1+1+2=4 pts] Image 2

29. [1+1+2=4 pts] Image 3

30. [1+1+2=4 pts] Image 4