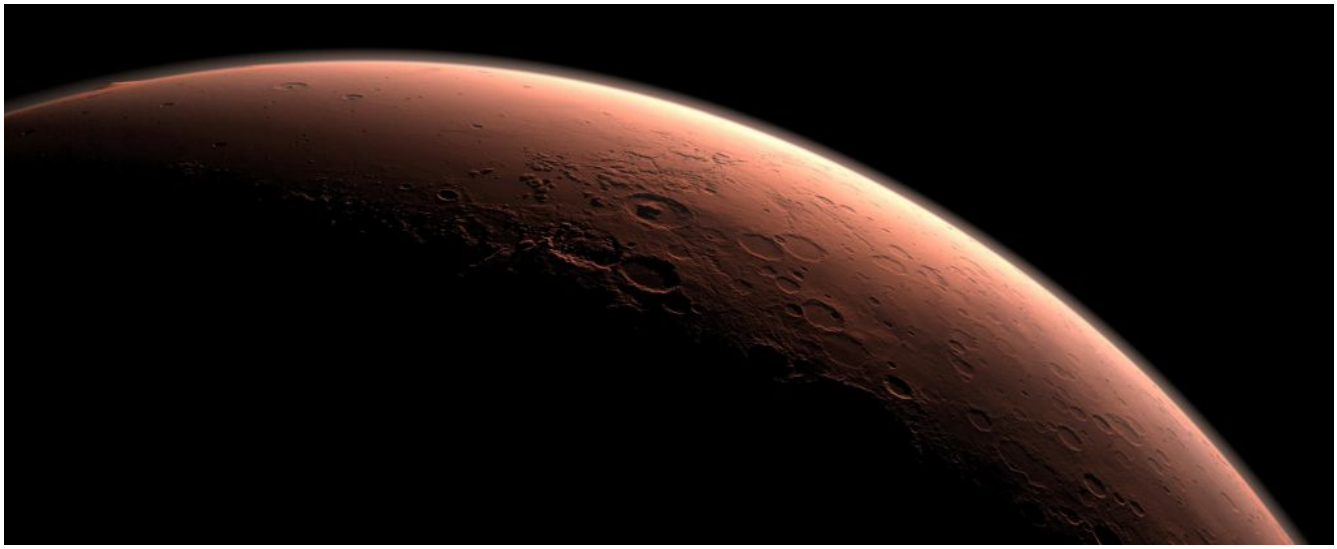
Sierra Vista Invitational
Division B
Solar System

February 4, 2023



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Additional Instructions

- Only what is on the answer sheet will be graded.
- You will have 50 minutes to complete the test.
- You are allowed one 8.5" by 11" sheets of paper with any content on both sides.

Team Number: _____ Team Name: _____

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Section A: Multiple Choice. Select the best answer, there is no penalty for guessing. (20 pts)

1. Which of the following is closest to the thickness of the crust of Enceladus?
    a. ~0.01 km
    b. ~0.1 km
    c. ~1 km
    d. ~10 km
    e. None of the above

2. How many amino acids are common to most of life?
    a. 20
    b. 30
    c. 10
    d. 5
    e. 2

3. Which of the following is used to power the radioisotope power supply of the spacecraft in *Image C*?
    a. U-235
    b. Pu-238
    c. U-238
    d. Pu-230
    e. Kr-220

4. In the drake equation, the variable f_i represents which of the following fractions?
    a. Earth sized planets with life
    b. Suitable stars for life
    c. Stars with planets
    d. Planets with intelligent life
    e. The lifetime of life

5. High-order approximations of the drake equation lead to which of the following conclusions?
    a. The extremophile paradox
    b. The nebular hypothesis
    c. The fermi paradox
    d. The faint young sun paradox
    e. None of the above

6. A possible starting material for abiogenesis, a PAH is a polycyclic_:
    a. amorphous hydrocarbon
    b. aromatic hydrocarbon
    c. agitated hydrogen
    d. activated hydrocarbon
    e. hydrocarbon

7. Which of the following is the chemical formula for heavy water?
    a. DO
    b. H_3O
    c. H_2O_2
    d. H_2O
    e. D_2O

8. Which aspect of the DAVINCI+ mission will assist with knowledge on the formation of Venus?
    a. Emission spectroscopy
    b. Atmospheric analysis
    c. Absorption spectroscopy
    d. High resolution imaging
    e. None of the above

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9. *Image E* is an artist's rendition of a planet which was approximately how far from the Earth when discovered?
    a. ~100 ly
    b. ~200 ly
    c. ~1000 ly
    d. ~800 ly
    e. ~500 ly

10. Which of the following is true about the condition of habitability/life of a planet around a red dwarf?
    a. Lower possible lifetime
    b. Increased productivity
    c. Greater habitability
    d. Greater potential for life
    e. Greater instability

11. The TESS satellite is most sensitive in which of the following bands?
    a. Visible light
    b. NIR light
    c. LWIR light
    d. UV light
    e. Radio light

12. The image captured in *Image F* was taken by which of the following missions?
    a. Cassini-Huygens
    b. Phoenix
    c. Curiosity
    d. Opportunity
    e. Spitzer

13. Proxima centauri is known as which of the following?
    a. A brown dwarf
    b. A MGVCN
    c. A flare star
    d. A red giant
    e. A YSO

14. Imagine a comet at perihelion. If you face the direction of the gas tail from the sun and the comet moves left, the dust tail is:
    a. Straight ahead
    b. Slightly to the left
    c. Slightly to the right
    d. Facing outwards
    e. None of the above

15. The last mission to visit Venus before the year 2000 was:
    a. Mariner 10
    b. Pioneer 10
    c. Upwelling
    d. Messenger
    e. Cassini-Huygens

16. What feature on Mars is most directly related to the sublimation of CO2?
    a. Ice formation
    b. Strong winds
    c. Dust storms
    d. Cirrus clouds
    e. All of the above

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17. What colors the atmosphere of Titan orange?
    a. Methane
    b. Hydrocarbon smog
    c. Nitrogen smog
    d. Tholins
    e. Organic compounds

18. Which of the following is most true of the members of the TRAPPIST-1 system?
    a. They share similar colors
    b. They share similar luminosity
    c. They share similar densities
    d. They share similar periods
    e. They are entirely different
    f.

19. Which of the following is not a type of asteroid in the solar system?
    a. C-type
    b. K-type
    c. M-type
    d. S-type
    e. All of the above

20. A popular alternative proposed for carbon in building life is:
    a. Potassium
    b. Germanium
    c. Sulfur
    d. Silicon
    e. Strontium

Section B: Object-Specific Knowledge. (75 pts)

1. Refer to *Image A* and *Image B* at the start of the following section. (33 pts)

    a. What body is depicted in both images? (1 pt)
    b. Name the general features that dominate the surface of this object (as seen in the image). What are they composed of? (2 pts)
    c. Describe how the previously named features were formed on the surface of this body. (2 pts)
    d. How does the existence of such features indicate habitability on this body? Describe the relationship between this feature and how it implies the existence of other possible features on the body. (3 pts)
    e. Describe the layers that compose this object. (4 pts)
    f. Which spacecraft took images A and B (1 pt), and in what year (1 pt)? What image on the image sheet displays this spacecraft? (1 pt)
    g. What is the difference between the two images? (2 pts) Are they images of the same landscape? (1 pt)
    h. What instrument on the spacecraft likely took the images? (1 pt) Describe why that instrument is the most appropriate for this image out of all the instruments on the spacecraft. (2 pts)
    i. How does this object receive thermal energy? Describe any source(s) in detail. (4 pts)
    j. What other image on the image sheet displays this object? (1 pt)
    k. What feature is being displayed in this image? (Hint: Look towards the edges) (2 pts)
    l. What is the primary chemical composition of this feature? (2 pts)
    m. What is the significance of proving the existence of this feature, in terms of habitability? (3 pts)

2. Refer to *Image D* for the following questions (26 pts)

    a. What object is depicted in the image? (1 pt)
    b. Name another designation for the object. (1 pt)
    c. What spacecraft and instrument took this image? (2 pts)
    d. What two instruments on this spacecraft can measure infrared thermal emissions? (2 pts)
    e. Describe the formation process of this object. (3 pts)
    f. What is the name of the effect that allowed this object to obtain it's current orbit? (1 pt)

g. Describe the process by which this effect works. (3 pts) What kinds of objects does this effect apply to? (1 pt)
h. Where did this object likely initially form? (1 pt)
i. What is the image from the image sheet has a similar type/composition as the object in *Image D*? (1 pt)
j. What is the name of this object? (1 pt) What spacecraft has most closely observed it? (1 pt)
k. This object has provided a great deal of insight in the processes undergone by comets. Particularly, scientists have reevaluated previous hypotheses regarding the formation of the coma. Describe the process that is now thought to decompose carbon dioxide and water ices into the coma. Include specific terminology. (4 pts)
l. What specific compound (an amino acid), extremely relevant to abiogenesis, was found on this object? (2 pts)
m. Describe the density of this object, compared to Earth. (2 pts)

3. Refer to *Image G* for the following questions (16 pts)

a. What object is depicted in the image? (1 pt)
b. This object is known to contribute to the rings of Saturn. What is the name of the ring section that it contributes to? (2 pts)
c. What general region of this object does the image depict? (2 pts)
d. Which spacecraft took the image? (1 pt)
e. Two craters are visible towards the center of this image. What are their names? (2 pts)
f. This object is in orbital resonance with another object with a similar orbit around Saturn. What is the name of this other body? (1 pt)
g. What process enables this object to rccieve the majority of its thermal energy? (1 pt)
h. How does this resonance allow for this thermal energy to be sustained for a longer period of time? (3 pts)
i. Evidence has been discovered on this object that may suggest hydrothermal activity. Why is the existence of hydrothermal activity relevant for the habitability of this object? (3 pts)

Part C: Theory. (88 pts)

1. Energy Balance (27 pts)

    a. What is the "energy balance" of a planet? (2 pts) Name both sources this energy traditionally comes from. (2 pts).
    b. What is a positive, negative, and neutral energy balance? (3 pts) Which is the most suitable for a planet to be habitable? (2 pts)
    c. Categorize the following planets in terms of having a positive, negative, or neutral energy balance: Earth, Venus, and Mars. (3 pts)
    d. Imagine planet A is situated 0.5 AU from its host star. Planet B is 1 AU from the same star. What is the ratio of solar flux received at Planet A to that of Planet B? (3 pts)
    e. If the solar flux at planet B is 1200 W/m^2, what is the solar flux at planet A? (3 pts)
    f. Which planet has a solar flux more similar to Earth's? (1 pt) Which planet would you then guess is within the habitable zone of the star? (2 pts)
    g. Draw a rough sketch of the relation between the distance to a star and the solar flux that reaches the atmosphere. Only draw Quadrant 1. Let the y-axis represent the percentage of energy and the x-axis represent the distance (units are not required). y should equal 1 at x=0, and should equal 0.5 at x=1. Label the point at x=2. (6 pts)

2. Kepler's Laws (15 pts)

    a. Suppose you have a comet in orbit, in an ellipse with the Sun at one of its foci. Which law describes this shape? (1 pt) Which law describes the period of this orbit? (1 pt)
    b. What property of an orbit must be true for Kepler's second law to hold true for an orbit? (Not an orbit type, think of properties from physics) (2 pts)
    c. How many orbit types are possible in a traditional keplerian orbit? (2 pts)
    d. The total area of an ellipse can be described by the expression $A = \pi ab$, where a and b describe the semi-major and semi-minor axis of the ellipse. Imagine a comet sweeps out an area of $\frac{\pi bc}{4e}$ in a time interval t, where e is the eccentricity of the orbit. What fraction of the total period (T) of the orbit is this? (Hint: remember Kepler's second law and that e=c/a!) (5 pts)
    e. Using your answer from *Part d*, if the total period is $8 * 10^8 s$, what was the time interval t? (4 pts)

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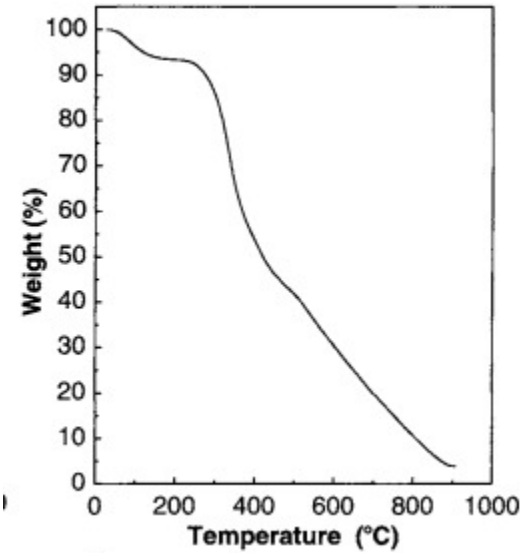
3. Proteins (8 pts)

The graph below displays the relationship of protein decomposition with temperature.



a. What is another name for this process? (1 pt)
b. How does this process work? In particular, what component of the protein is decomposed with heat? (2 pts)
c. What is the significance of this graph for habitability in our solar system? (1 pt) Which objects specifically exclude from harboring carbon-based life in our solar system? (2 pts)
d. What is the most common everyday example of this process in the modern world? (2 pts)

4. Transits (16 pts)

Typically, a transit's "depth" is defined by the equation:

$$Depth = \left(\frac{R_{planet}}{R_{star}}\right)^2$$

a. What does transit depth mean? (3 pts)

b. Why is the ratio of the radii squared? (2 pts) What physical property does it represent? (1 pt)
c. Imagine a function, F, which takes in a time-signal f(t) and decomposes it into N components of wavelengths that combine/add to form f(t). In this case, f(t) is incoming flux as a function of time. Provide a detailed explanation of how the function could be used to aid the research of exoplanet systems. (4 pts)
d. Suppose you are viewing a system, with *P* watts per meter squared of flux visible from the Earth. Over a period of 4 days, you view three consecutive dips in the flux of the star. One dip leaves the flux at x*P, the next one is y*P, and the last one is z*P, where x is greater than y which is greater than z, and all three are decimals are between 0 and 1. This pattern repeats indefinitely for this system. Assuming there are two bodies other than the central star, what is the significance of x, y, and z? Describe the physical system, and each component's relation to the variables. (6 pts)

5. Spectra (22 pts)

a. Traditionally, when light passes through a gas of some medium, its behavior is defined by Kirchhoff's laws. What are the three types of gases in Kirchhoff's laws? (3 pts)
b. Which of these types best describes the case of a planetary atmosphere? Why? (3 pts)
c. Imagine a continuous spectrum of photons passes through a planetary atmosphere, and after performing a spectroscopic analysis on the flux received the output is visible in *Image P*. If the x-axis is measured in nanometers, what gas would you believe the atmosphere contains? Write both the chemical formula and common name (4 pts).
d. Does the presence of this substance more closely imply life or habitability? (1 pt) Why or why not? (2 pts)
e. What biological process can produce this substance? (2 pts)
f. Does the spectral feature necessarily have to come from the planetary atmosphere? (1 pt) Why or why not? (3 pts)
g. What type of telescope would be the best for detecting this gas in a planetary atmosphere? (Hint: Think location). (1 pt) Why? (2 pts)