2006 NSO Finals/Solar System Event **Mars: The Fourth Rock**

Directions: Record all answers on the "Student Response Sheet." Do not write on the map. You may write on this exam, and you may separate the pages. All responses must be written legibly. You will have 50 minutes to complete the exam.

Part I: Kepler's Laws of Planetary Motion

Tycho Brahe, a sixteenth century astronomer, was so intrigued with the unusual orbital pattern of Mars that he dedicated much of his life to meticulously observing and recording its motions. Brahe's records fell into the hands of Johannas Kepler who believed that unlocking the mysteries of the orbit of Mars held the key to an understanding of the orbits of all other planets as well.

Utilizing a trial-and-error approach to studying the orbit of Mars and adjusting as needed, Kepler formulated three laws of planetary motion:

- First Law: The orbit of a planet around the Sun is an ellipse with the Sun at one focus.
- Second Law: A line joining a planet and the Sun sweeps out equal areas in equal intervals of time.
- Third Law: The squares of the sidereal periods of the planets are proportional to the cubes of their semimajor axes.

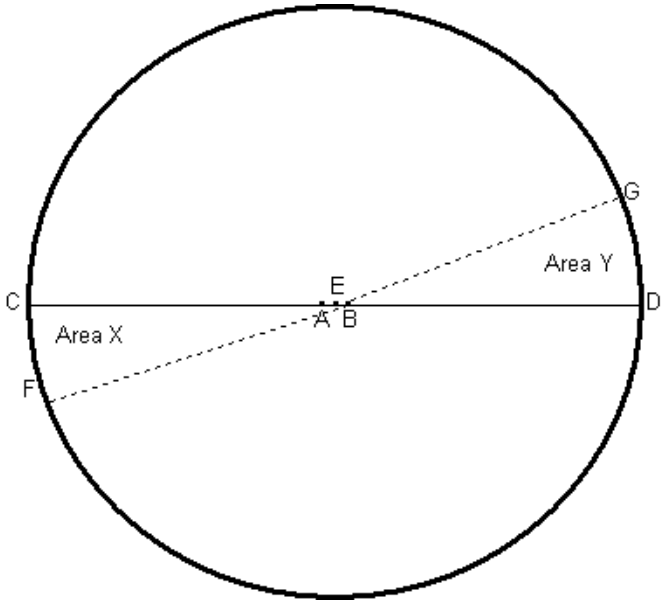

Figure 1

Figure 1: The orbit of Planet Mars around the Sun. Assume that the time required for Mars to cover the distance D to G is equal to the time required to cover the distance from C to F.

1. Given the parameters stated in the instructions above, which of Kepler's three laws of planetary motion states that Area X is equivalent to Area Y?

2. Which of Kepler's three laws explains the repetitive and consistent changes in the orbital speed of a planet?

3. Assume that Mars is orbiting the Sun in a counterclockwise direction. Is Mars moving faster as it approaches point D **or** point C?

4. Is the Sun located at point A, B, **or** E?

5. Of the nine recognized planets in our solar system, Neptune's orbit is the least eccentric. Would the foci of Neptune's orbit be spaced closer together **or** farther apart as compared to those of the other planets?

6. Does the letter C **or** D mark the location of Mars when at aphelion?

7. Does the letter C **or** D mark the location of Mars when at perihelion?

8. Line CD is the longer of two lines about which the ellipse is symmetrical. What term or phrase identifies this line?

9. What term refers to the distance between points E and D (or C and E)?

10. Which of Kepler's laws quantifies the observation that more distant planets have longer periods of revolution about the Sun?

11. Which of Kepler's laws is illustrated by the line graph in Figure 2?

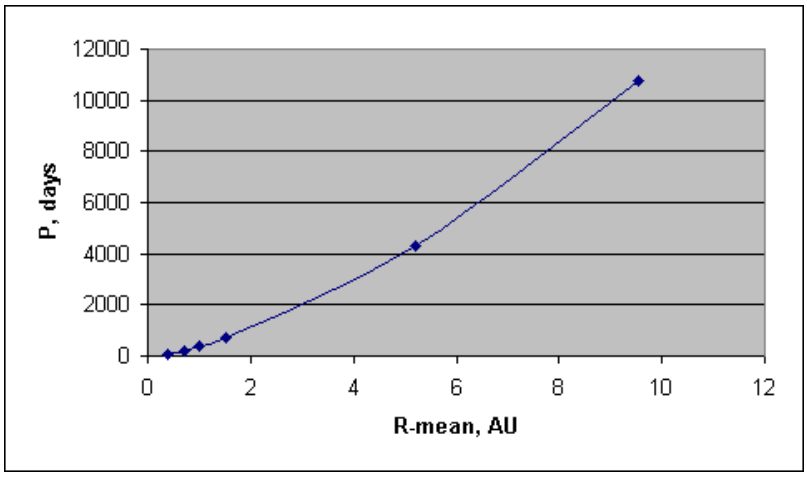

Figure 2

Part II: Atmosphere, Temperature, and Seasons

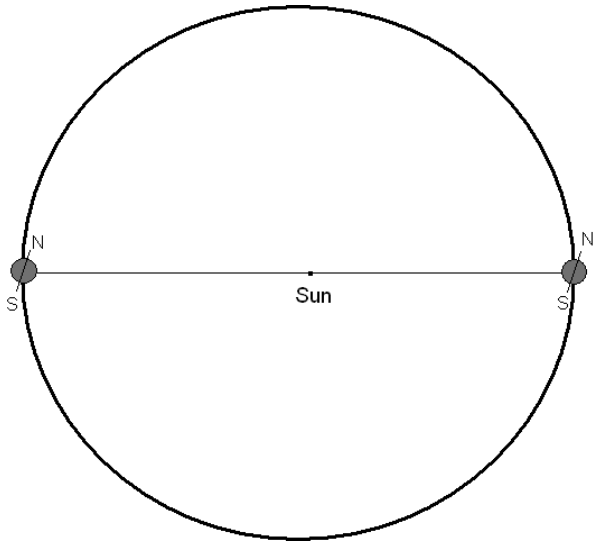

Figure 3: Seasons on Mars

The tilt of its rotation axis and its revolution around the Sun determine the seasons on Mars. As discussed earlier, the Martian orbit is elliptical with the Sun positioned at one focus of the ellipse. The orientation of the orbit in Figure 3 is the same as in Figure 1. The line through the planet represents its rotation axis with north at the upper right at all times. At the very small scale at which the orbit is drawn, there seems to be little difference between its distances from the Sun during the winter and summer seasons. In reality this difference is 43 million kilometers, sufficient to create some variation in surface temperatures.

12. Is Mars at perihelion **or** aphelion during the southern summer?

13. a. Does the southern or northern hemisphere receive a higher percentage of solar radiation during its respective summer?

    b. Mars rotates 667 times during each orbit around the Sun. Approximately how many days pass between maximum and minimum ice coverage on each of its poles?

14. a. Is the northern summer shorter or longer that the southern summer?

    b. Is the northern winter shorter or longer that the southern winter?

    c. Would the northern or southern hemisphere have the harshest winter weather conditions?

Atmospheric pressure on Mars changes seasonally because the temperature is cold enough for some of the carbon dioxide to freeze out during the winter and "snow" onto the polar icecap. This “freezing out” greatly reduces the amount of carbon dioxide remaining in the atmosphere. During the summer, when the polar cap warms up again, the carbon dioxide returns to the atmosphere.

15. Why does water freeze out of the atmosphere before carbon dioxide freezes out?

16. How does condensation and sublimation of its atmospheric gases affect the atmospheric pressure on Mars during the Martian seasonal cycle?

17. As the northern winter gradually turns to spring followed by summer, the frozen carbon dioxide and water sublime off the pole and reenter the atmosphere. Does this sublimation create a high **or** low pressure system over the north pole?

18. As the gases frozen into the icecap of the northern pole begin to sublime, the atmospheric gases over the southern pole begin to freeze out, resulting in an increase in the size of the southern icecap. Does the removal of these gases from the southern skies result in a high **or** low pressure system over its south pole?

19. Do prevailing winds generally blow from (a) areas of high pressure to areas of low pressure or (b) areas of low pressure to areas of high pressure?

20. Assume that you are near the Martian equator during spring in the northern hemisphere. In which direction do the prevailing winds blow as winter in the northern hemisphere gradually gives way to spring and summer?

21. Why do most major dust storms occur when Mars is at perihelion?

Major factors that cause variations in surface temperature for a given location on Mars include:

a. climatic zone (latitude)
b. orbital eccentricity
c. distance from the Sun
d. day/night (rotation)
e. atmospheric effects
f. seasons

22. Of the factors listed, which is most influential in determining temperatures?

23. Of the factors listed, which is least influential in determining temperatures?

24. What effect does surface elevation of a planet have upon the density of the atmosphere directly above it?

25. Is the northern **or** southern polar region higher in elevation? (Refer to the Topographic Map of Mars.)

26. Would the northern **or** southern polar region have a denser atmosphere?

During the past several years astronomers have observed that the Martian poles are shrinking in size on an average annual average.

27. a. Explain how this shrinking might affect global climate should that trend continue for many years.

    b. How might this condition relate to similar observations on Earth?

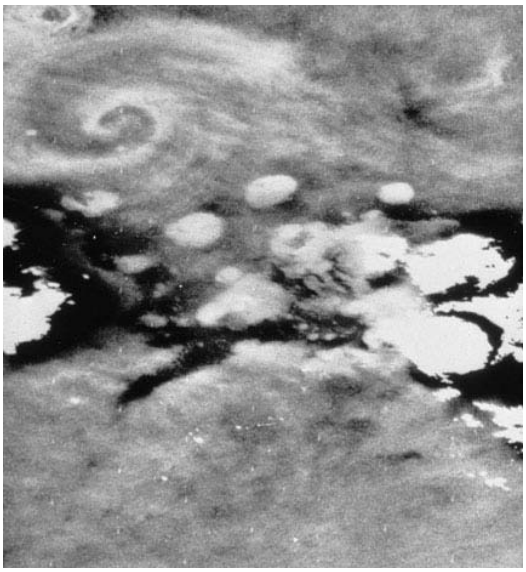

Figure 4: A Martian cyclone appears in the upper left of this Image
Image credit: Albert T. Hsui, University of Illinois

28. Mars rotates in the same direction and has a similar rate of rotation as Earth. A Martian cyclone appears in the upper left in the photo in Fig. 4.

    a. Which Martian hemisphere is shown in the image in Figure 4?

    b. Upon what clue did you base your response to question 28a?

    c. What force causes a wind flow, such as a cyclone, to rotate on a spinning planet?

Part III: Geologic Activity and Features

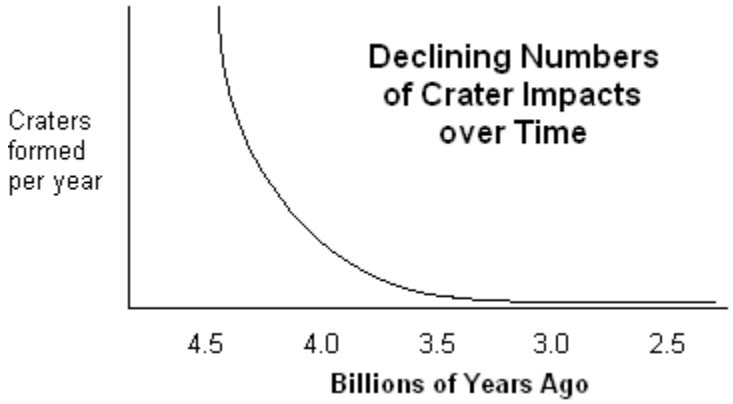

Figure 5: Graphic depiction of the relative numbers of objects that impacted the surface of Mars over its approximate 4.6 billion year history.

29. What caused the rapid decline in the number of impacts during the early history of Mars?

30. Name two types of large solid objects that have the potential of striking the surfaces of the planets and their satellites at the present time.

31. Identify three regions of the solar system where the objects you listed in question 30 may have originated?

32. Craters are among the more prominent features on the Martian surface. List <u>two</u> characteristics of craters that render them excellent indicators for determining the relative ages of large areas on the Martian surface.

Important background information! The large rectangular section on the Topographic Map of Mars has been created as a Mercator projection. In attempting to transfer features originally found on a spherical shape onto a flat surface, the features are gradually distorted as one travels farther northward and southward from the equator.

33. Would (a) elevation, (b) shape, (c) size, or (d) angles be distorted on a map drawn as a Mercator projection? There are <u>two</u> correct responses.

It is thought that the five large impact basins on the Martian surface were blasted out as five separate pieces of a single broken-up asteroid collided with Mars. The immense sizes of these impact craters are a direct result of the large mass of those impactors and the speed at which they were traveling immediately

prior to impact. These large chucks of asteroid material struck the surface of Mars at different times and at different locations.

34. Identify three of the five impact basins found on the surface of Mars.

35. Which impact basin is the deepest?

36. The deepest of these impact basins, identified in question 35, was blasted out by an asteroid fragment about the size of the largest asteroid in the Asteroid Belt. What is the name of the largest asteroid in the Asteroid Belt?

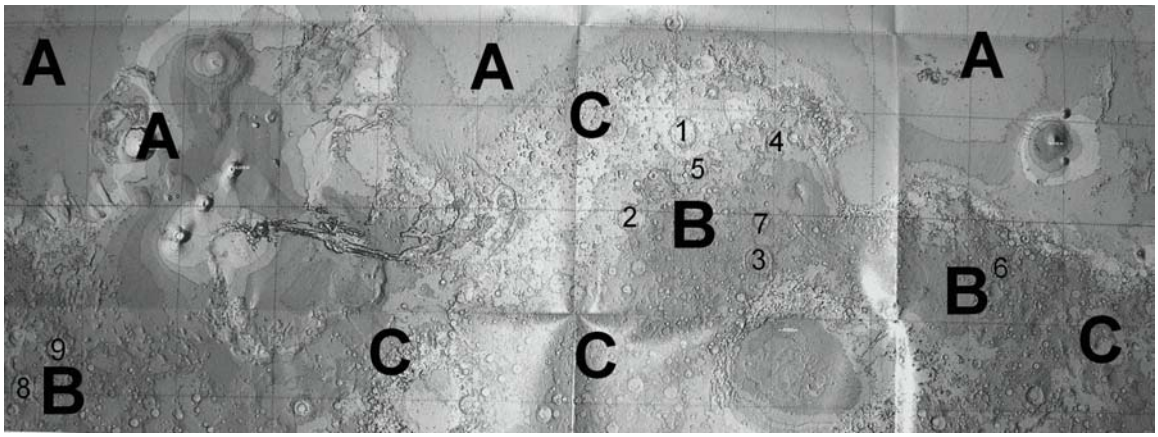

Figure 6a: The Topographic Map of Mars that you are using has been reproduced above and greatly reduced in size. The nine, largest impact craters, those having diameters ≥ 280 kilometers, are numbered from largest to smallest on the map. Their names and diameters are listed below. (Ignore the large capital letters for now.)

1. Cassini	540 km	6. Herschel	329 km
2. Schiaparelli	500 km	7. Schroeter	310 km
3. Huygens	495 km	8. Copernicus	280 km
4. Antoniadi	380 km	9. Newton	280 km
5. Tikhonravov	360 km		

37. Are the nine largest Martian craters (a) located within a general area or are they (b) scattered randomly about the Martian surface?

38. Locate several of these large craters on the large Topographic Map of Mars. From your observations, which one of the following statements best describes these large craters?

    a. They seem to have undergone severe erosion since their formation.
    b. Their walls are sharp and distinct, appearing as if they were recently formed.
    c. Many have been impacted by smaller impactors creating many smaller craters within them.
    d. Only statements “a” and “c” are true.
    e. Statements a, b, and c are true.

39. List <u>two</u> observations relating to the appearance of the walls of the small craters located on the northern lava plains of Mars.

40. Why are there no really large impact craters on the northern lava plains of Mars?

41. Why are there so few impact craters per unit area on the northern lava plains of Mars?

The geologic history of Mars has been divided into three very long periods of time, each period referred to as an “epoch.”

- **Noachian** epoch – formation of “large and small craters”
- **Hesperian** epoch – formation of “small craters only”
- **Amazonian** epoch – formation of “few craters”

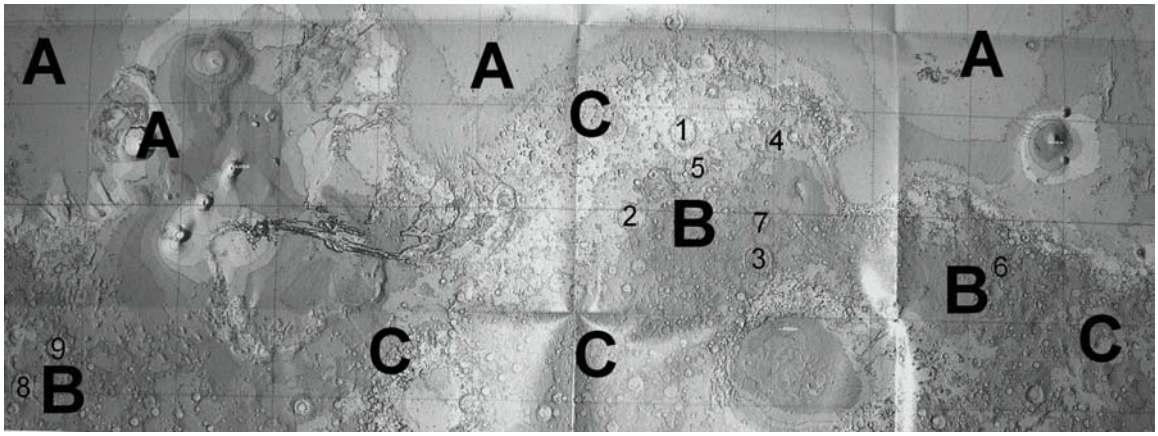

Figure 6b: Topographic Map of Mars reprinted here for your convenience.

Each set of letters superimposed onto the map identifies a particular region that retains a record of a single epoch. The areas marked “A” cover much of the northern hemisphere of Mars. The areas marked “B” represent another epoch, but are physically separated by a significant distance. The remaining areas, marked “C,” include a small portion of the northern hemisphere plus most of the southern hemisphere. The numbers identify the largest craters in order of size.

42. During which epoch was area “A” formed?

43. During which epoch was area “B” formed?

44. During which epoch was area “C” formed?

The bright, solid orange area on the Topographic Map is a large uplifted area known as the Tharsis bulge. This bulge covers approximately one-fourth the surface area of Mars and is about the size of Earth’s North American continent. Four huge conically-shaped volcanoes, a large caldera named Alba Patera, a 5000-mile rift valley, and several other smaller features are associated with this bulge.

45. What is the approximate elevation of the Tharsis bulge?

46. The Martian crust varies from very thick in the southern hemisphere to quite thin in the northern hemisphere. What evidence indicates that the crust underlying the Tharsis bulge is relatively thin?

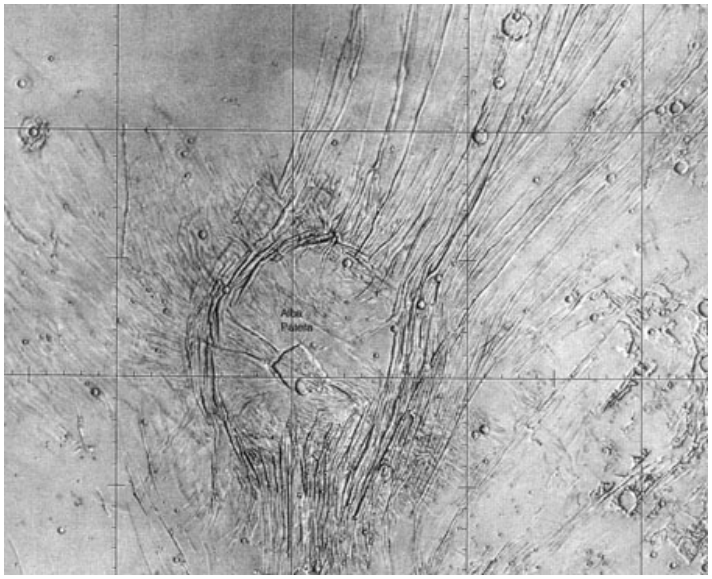

Figure 7: Alba Patera. Albert T. Hsui, University of Illinois

47. To the north of the series of three shield volcanoes situated on the Tharsis bulge is a volcanic caldera named Alba Patera shown in Figure 7.How does this volcanic structure differ from the shield volcanoes? List <u>two</u> characteristics that are unique to this volcanic structure.

The islands of the Hawaiian chain were created as the plate on which they formed slowly passed over a hot spot through which lava spewed upward to "grow the volcano." Growth of each individual volcanic island ceased once the volcano had passed over the hot spot. Earth's crust has been divided into numerous plates of various sizes whereas Mars has only a single large plate.

48. Similar to the islands of the Hawaiian chain, Olympus Mons and its neighboring volcanoes are shield volcanoes built by a series of many successive lava flows. Unlike the islands of the Hawaiian chain however, Olympus Mons and its companions grew to enormous sizes. What special Martian characteristics permitted Oympus Mons and its neighboring shield volcanoes to grow so large?

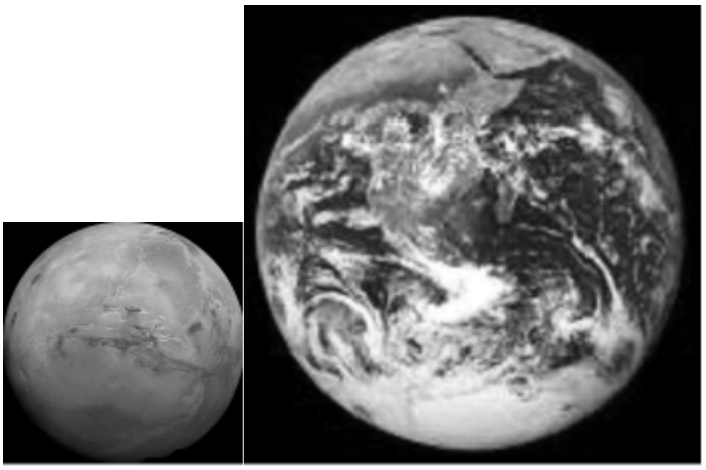

Figure 9: Mars has only one tenth the mass of Earth

49. How did the overall mass of Planet Mars effect the growth of Olympus Mons?

50. While staring into the distance, Earth's horizon appears to be very far away. Were you standing on the surface of Mars, would the horizon appear to be (<u>a</u>) at nearly the same distance as it would be on the Earth **or** (<u>b</u>) much closer to you?

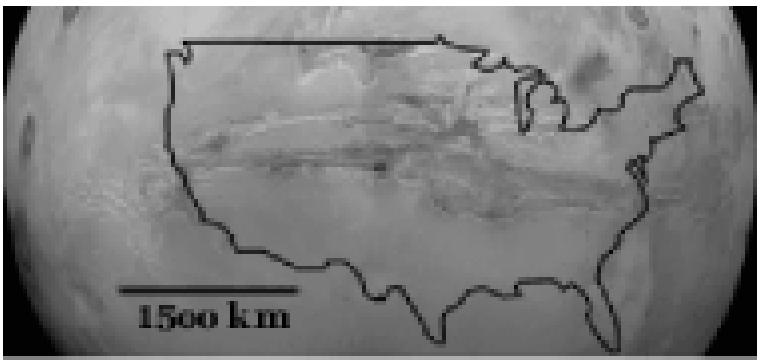

Figure 10: Valles Marineris is as long as the United States and spans about 20 percent (1/5) of the entire distance around Mars.

51. Some parts of Valles Marineris run as deep as 7 km (4 mi) and as wide as 200 km (125 mi). If you were standing on one side of Valles Marineris at its widest point, why would you not be able to see the other side?

52. Valles Marineris was named for

    a. an early Martian space mission.
    b. a sixteenth century observer of Planet Mars.
    c. a Greek goddess.
    d. the author of Stranger in a Strange Land.

53. Locate the Viking 1 and Pathfinder landing sites on Chryse Planitia in the Northern Hemisphere of Mars, slightly left of center. List two types of evidence in this vicinity that tend to support the theory that liquid surface water may have been present in this vicinity sometime in the distant past?

54. a. My partner and I rate this exam as:

        a. Much too difficult.

        b. Challenging, but fair.

        c. Relatively easy.

        d. Much too easy.

    b. Add a comment if you wish.