

**Planet Mars**

Name(s): \_\_\_\_\_

**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 Johannes 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.

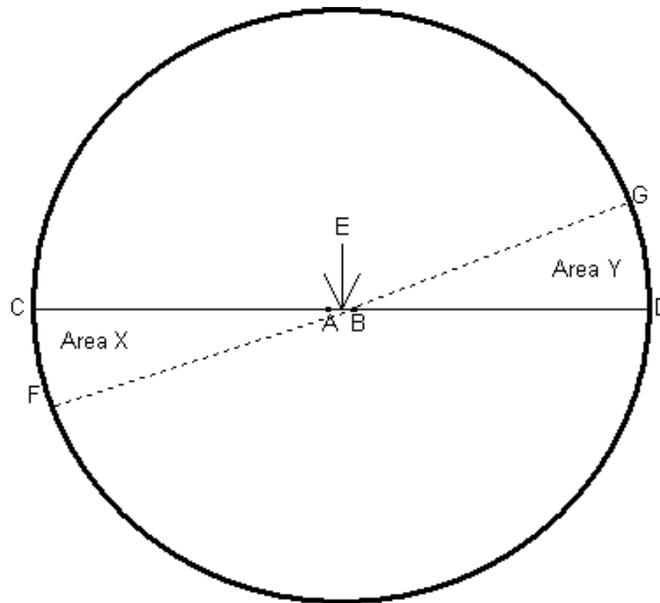


Figure 1

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 an 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? \_\_\_\_\_

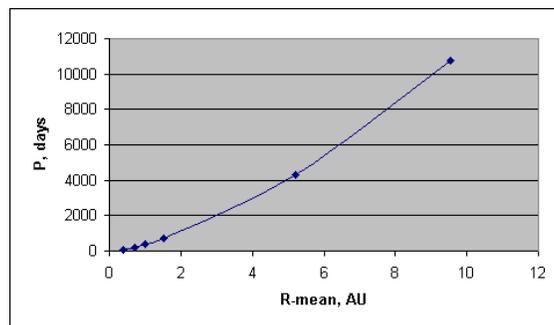


Figure 2

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

**Part II:** Atmosphere, Temperature, and Seasons

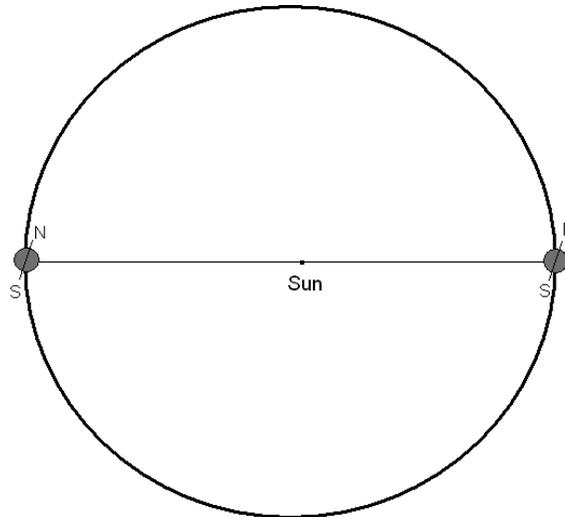


Figure 3: Seasons on Mars

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. Martian north is toward the upper right. At the very small scale at which the Martian orbit is drawn in Figure 3, 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. Is the Martian north or south pole cooler during its respective summer?  
\_\_\_\_\_

b. Which polar cap – northern or southern – is larger in area during the poles' respective summers? \_\_\_\_\_

14. a. Compare the length and temperature of Mars' northern summer with that of its southern summer.

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- b. Compare the length and temperature of Mars' northern winter with that of its southern winter.

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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?  

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

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- 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?  

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- 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?  

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- 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?

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

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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? (or “distance from the Sun”) \_\_\_\_\_

23. Of the factors listed, which is least influential in determining temperatures? (or “orbital eccentricity”) \_\_\_\_\_

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

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25. Given that the southern polar region of Mars is higher in elevation, would the northern or southern polar region have a denser atmosphere?

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26. Assume that air pressure near the surface of Mars is  $1/100^{\text{th}}$  that of Earth and that Earth's atmosphere is 14.7 pounds per square inch at sea level. Determine the atmospheric pressure at the surface of Mars in pounds per square inch.

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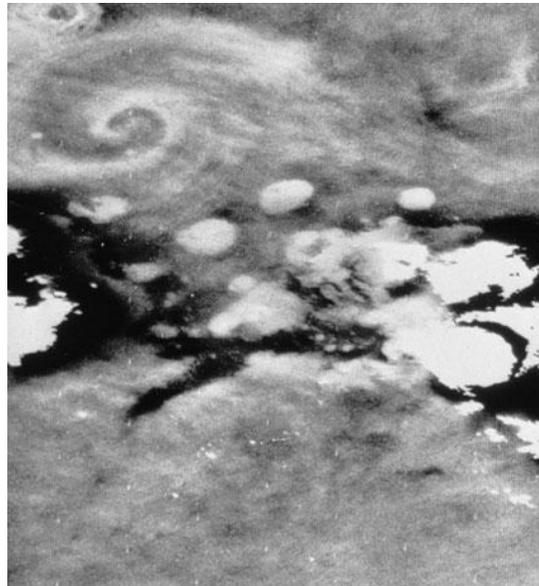


Figure 4: A Martian cyclone appears in the upper left of this Image  
Image credit: Albert T. Hsui, University of Illinois

27. 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? \_\_\_\_\_

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

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**Part III:** Geologic Activity and Features

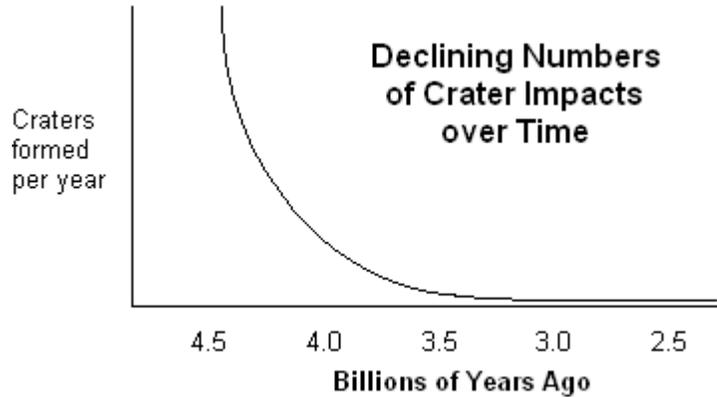


Figure 5: Graphic depiction of the relative numbers of objects that impacted the surface of Mars over its approximate 4.6 billion year history.

28. What caused the gradual decline in the number of impacts during the early history of Mars?

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29. 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.

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

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

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**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 Johannes 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.
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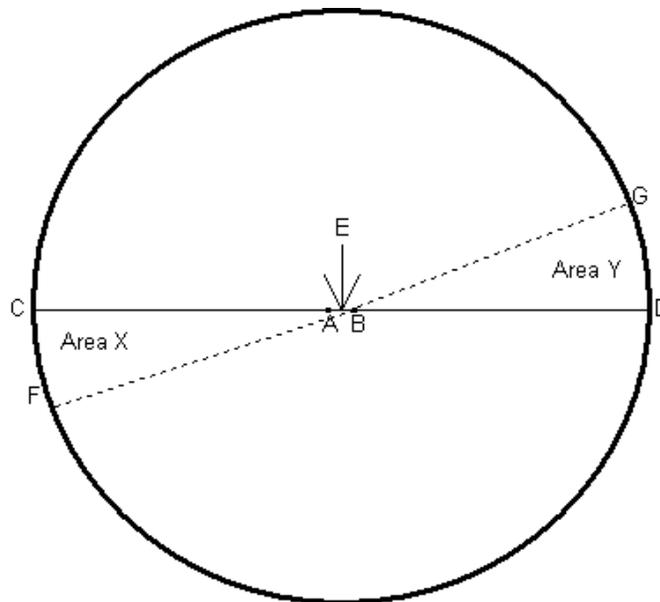


Figure 1

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?  
**Second**

## Planet Mars

## Answer Key, Page 2

- Which of Kepler's three laws explains the repetitive and consistent changes in the orbital speed of a planet? **Second**
- Assume that Mars is orbiting the Sun in a counterclockwise direction. Is Mars moving faster as it approaches point D or point C? **Point D**
- Is the Sun located at point A, B or E? **B**
- 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? **Closer together**
- Does the letter C or D mark the location of Mars when at aphelion? **C**
- Does the letter C or D mark the location of Mars when at perihelion? **D**
- Line CD is the longer of two lines about which an ellipse is symmetrical. What term or phrase identifies this line? **Major axis**
- What term refers to the distance between points E and D (or C and E)? **Semimajor axis**
- Which of Kepler's laws quantifies the observation that more distant planets have longer periods of revolution about the Sun? **Third**

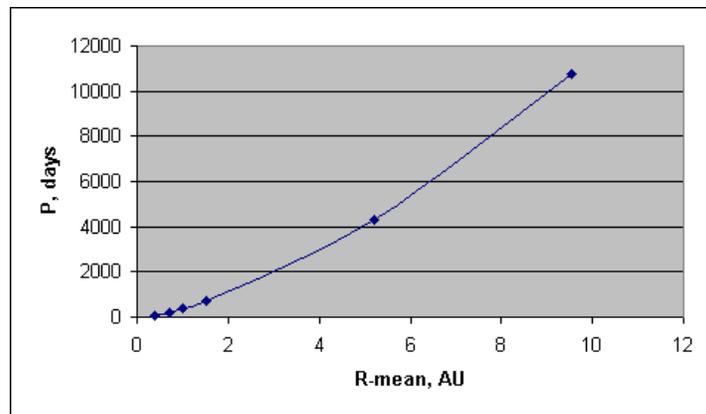


Figure 2

- Which of Kepler's laws is illustrated by the line graph in Figure 2? **Third**

## Part II: Atmosphere, Temperature, and Seasons

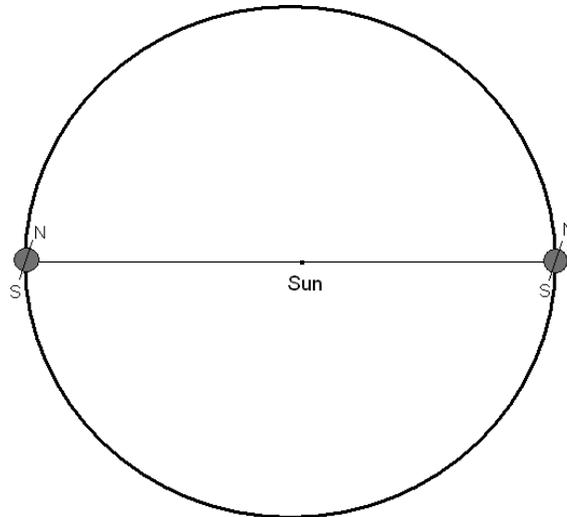


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The tilt of its rotation axis and its revolution around the Sun determine the seasons on Mars. As discussed earlier, the Martian orbit is elliptical with the Sun positioned at one focus of the ellipse. The orientation of the orbit in Figure 3 is the same as in Figure 1. The line through the planet represents its rotation axis. Martian north is toward the upper right. At the very small scale at which the Martian orbit is drawn in Figure 3, 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? **Perihelion**
13. a. Is the Martian north or south pole cooler during its respective summer?  
**North**
  - b. Which polar cap – northern or southern – is larger in area during the poles' respective summers? **Northern**
14. a. Compare the length and temperature of Mars' northern summer with that of its southern summer. **The southern hemisphere has shorter, hotter summers (The northern hemisphere has longer, cooler summers.)**

- b. Compare the length and temperature of Mars' northern winter with that of its southern winter. **The southern hemisphere has longer, colder winters. (The northern hemisphere has shorter, warmer winters.)**

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? **Carbon dioxide has a much lower freezing point.**
16. How does condensation and sublimation of its atmospheric gases affect the atmospheric pressure on Mars during the Martian seasonal cycle? **Atmospheric pressure increases as CO<sub>2</sub> sublimates; and decreases as it condenses back into snow and ice.**
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? **High pressure system**
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? **Low pressure system**
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?

## Planet Mars

## Answer Key, Page 5

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? **North to South**
21. Why do most major dust storms occur when Mars is at perihelion? **Mars is closest to the Sun at perihelion. At this time, the Sun's energy heats the southern atmosphere a bit more thus increasing the temperature range between the northern and southern hemispheres. This greater difference in temperatures creates stronger winds sometimes resulting in planet-wide dust storms.**

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

- |                             |                         |
|-----------------------------|-------------------------|
| a. climatic zone (latitude) | d. day/night (rotation) |
| b. orbital eccentricity     | e. atmospheric effects  |
| c. distance from the Sun    | f. seasons              |
22. Of the factors listed, which is most influential in determining temperatures? **c** (or "distance from the Sun")
23. Of the factors listed, which is least influential in determining temperatures? **b** (or "orbital eccentricity")
24. What effect does surface elevation of a planet have upon the density of the atmosphere? **The atmosphere is most dense at lower elevations.**

25. Given that the southern polar region of Mars is higher in elevation, would the northern or southern polar region have a denser atmosphere? **Northern**
26. Assume that air pressure near the surface of Mars is  $1/100^{\text{th}}$  that of Earth and that Earth's atmosphere is 14.7 pounds per square inch at sea level. Determine the atmospheric pressure at the surface of Mars in pounds per square inch. **0.147 pounds per square inch**

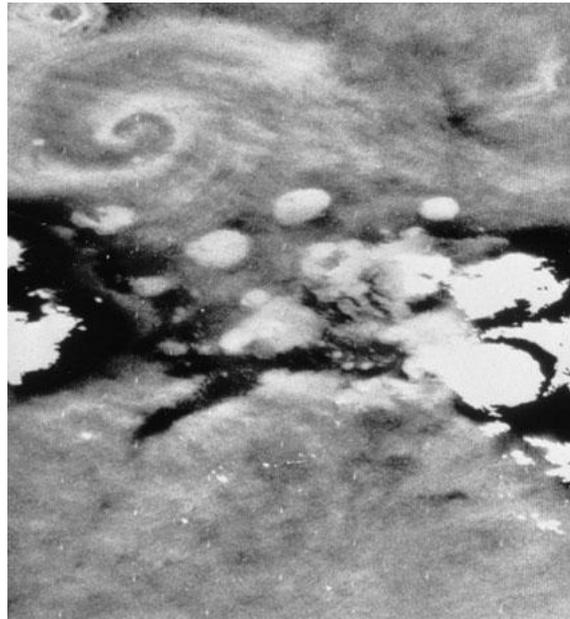


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Image credit: Albert T. Hsui, University of Illinois

27. 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.
- Which Martian hemisphere is shown in the image in Figure 4? **Northern**
  - Upon what clue did you base your response to question 28a? **Counter-clockwise direction of the spinning cyclone as indicated by the direction of the spiral pattern in the clouds**
  - What force causes a wind flow, such as a cyclone, to rotate on a spinning planet? **Coriolis effect**

## Part III: Geologic Activity and Features

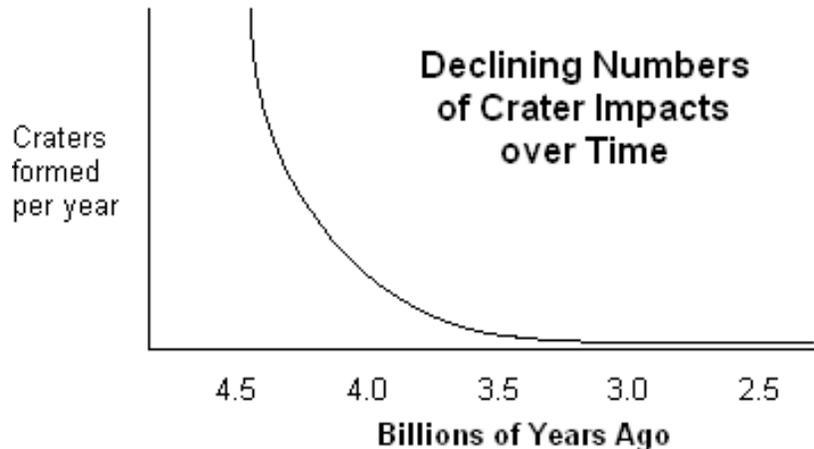


Figure 5: Graphic depiction of the relative numbers of objects that impacted the surface of Mars over its approximate 4.6 billion year history.

28. What caused the gradual decline in the number of impacts during the early history of Mars? **There were a finite number of large solid bodies available, i.e. the more of these large solid bodies that impacted the surface, the fewer remained.**
29. 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. **Comet nuclei and asteroids**
30. Identify three regions of the solar system where the objects you listed in question 30 may have originated? **Asteroid Belt, Kuiper Belt, Oort Cloud**
31. Craters are among the more prominent features on the Martian surface. List two characteristics of craters that render them excellent indicators for determining the relative ages of large areas on the Martian surface. **Possible responses: density (number of craters per given equal areas); size; amount of erosion; size to some extent**