SUNSPOTS **Test Answer Key**

The following answers reflect content contained in the Sunspots lesson. You may want to devise a grading rubric based on relative values of multiple choice answers and levels of detail.

History Section

1. **Why is the Sun important to life on Earth? Please list three ways light and heat from the Sun help us to live.**
   1. The Sun provides energy for plant photosynthesis, the foundation upon which other life forms depend; 2.Its light and heat make Earth a temperate environment; 3.Its light and heat power wind and weather systems which create water cycles.

2. **Why did some ancient cultures observe and worship the Sun?**
   Ancient cultures thought the Sun was a god since it had the power to provide light, warmth, and the energy to make plants grow. They attributed special god-like qualities to the Sun. The early cultures wanted to understand the powerful Sun and please it so its life-giving gifts would continue, and to prevent "punishment" in the form of droughts and flooding rains.

3. **How did Europeans such as Galileo observe sunspots?**
   At first Europeans used their eyes, and looked directly at the Sun when there was fog or at sunset, when the Sun was less bright After the telescope was invented by the Dutch in 1608, European astronomers such as Galileo used the telescope to observe sunspots. Looking directly at the Sun can cause irreversible damage to the eyes.

4. **We should never look directly at the Sun. However, can you briefly describe a safe and easy way to observe sunspots?**
   The 'projection method' is a good way to view the Sun safely. Mount a telescope or pair of binoculars on a tripod, point it toward the Sun, and place a flat white surface behind the eyepiece upon which the image of the Sun can be projected. Never look directly through the eye piece to aim at the Sun, as that can cause severe eye damage. A cardboard screen placed around the telescope or binoculars, with a hole cut to the outside diameter, will create a shadow behind the apparatus which makes the projected image more visible.

5. **Scientists in the 1600's did not yet know what caused sunspots. What ideas, beliefs, and opinions did they have about them?**
   Many Europeans at that time believed that the heavens were perfect or without irregularities, following the ideas of Aristotle. When scientists first saw sunspots using telescopes they didn't know what they were. Some, like Galileo, believed the spots were part of the Sun itself. This belief caused an outrage among many people of the time since spots suggested imperfection in the heavens. Scientists who sought to maintain the older view thought the spots must be moons, clouds, or other planets orbiting around the Sun. This model could be consistent with the doctrine that the Sun was perfect and not flawed by spots.

<u>Modern Research Section</u>

6. **In Galileo's time (1564 – 1642) observers could only view the Sun in visible, or white light. Today, however, astronomers have very powerful telescopes which can observe the Sun in great detail, and in other wavelengths of light. Name any <u>two</u> types of non-visible light these new instruments can detect.**

Modern telescopic equipment using various filters and detectors can measure wavelengths in the non-visible light portions of the electromagnetic spectrum. These new instruments can detect ultraviolet, infrared, X-rays, and gamma rays.

7. List at least <u>two</u> facts about the Sun's mass, composition or structure.

Possible Answers:

- The Sun is the largest object in the solar system, and contains 98% of the solar system's mass.
- 100 earths could fit across the Sun's diameter.
- The Sun is made of about 90% hydrogen and 8% helium by mass, with other trace elements.
- The Sun is composed of a core, radiation zone, convection zone, chromosphere, and corona.
- The Sun is powered by nuclear fusion reactions in its core.
- The Sun's surface temperature is about 5,800 K.
- Its outer corona is much hotter: about 1 - 2 million K.
- The Sun has a strong magnetic field which is constantly changing.

8. How big is an average sunspot? (multiple choice question)

d. An average-sized sunspot is about the size of the Earth.

9. What happens in the Sun's convection layer? (multiple choice question)

e: a and d - Heat is transported to the surface by flows of hot plasma; cool plasma flows back toward the core.

10. What is the source of sunspots' magnetic fields? (multiple choice question)

b. moving currents of electrically charged particles

11. Can you describe what happens during the Sunspot cycle? How long does it take to complete a cycle?

The number of sunspots at any time rises and falls in a regular rhythm, cycling from low to high and back to low about every 11 years. Scientists now know that the Sun's magnetic field changes direction every 11 years, making a complete cycle in 22 years. Sunspots appear at high latitude early in each half of the cycle, and gradually appear closer and closer to the equator later in the cycle.

12. It has been speculated that the solar minimum affects the climate of the earth. Can you name one famous, unusually cold period in history that corresponds to low levels of solar activity?

The Oort Minimum (1010-1050); the Wolf Minimum (1280-1340); the Spörer Minimum; (1420 - 1530); the Maunder Minimum (1645-1715). Note: These are all part of what is now called "The Little Ice Age"

13. How does the Earth's magnetic field protect us?

The Earth's magnetic field is continually protecting us by deflecting energetic, charged particles and magnetic field of the solar wind. If it were not for the earth's magnetic field the charged particles would change the ionosphere and destroy the ozone layer, permitting high levels of harmful UV radiation to reach the Earth's surface.

14. What impact does space weather (geomagnetic storms) have on Earth?

f. all of the above - Satellites can be disabled or have their orbits decay; auroras can become more frequent and bright; power grids can be over loaded and cause power outages to cities and homes; radio transmissions can be drowned out

15. What is a sunspot? In the space below, please draw a picture of a sunspot, and label as many parts as you can. Draw the magnetic field lines around the sunspot(s).

Pictorial representations could include:

- Photosphere: the Sun's visible surface, upon which sunspots appear.
- Umbra: a dark, roughly circular central disk. The term umbra means "shade" in Latin.
- Penumbra: a lighter outer area that surrounds the dark umbra at center.
- Magnetic field loops: arcs created when magnetic fields push up through the surface, bringing some of the hot plasma with them. Loops end on the sunspots on the Sun's surface.
- Flares, or blobs of ejecta from a CME

16. How is a sunspot created? Describe what happens in the Sun to produce a sunspot.

Convection currents create a dense magnetic field loop. Local magnetic pressure causes it to bow out from the surface. Places where the magnetic field lines leave and re-enter the Sun's surface appear as the dark sunspots we observe. Inside the Sunspot high magnetic pressure causes lower gas pressure. This means the Sunspot is less dense, cooler, and darker than the surrounding photosphere.

Activity Section

17. Many scientists and astronomers study sunspots. Why is their research important?

Many answers are valid or partially correct:

- Scientists do not yet know everything about the Sun and how it behaves.
- Scientists study the Sun in order to learn about how it changes.
- Scientists want to know how the Sun effects our environment on Earth.
- If we can learn to predict when powerful solar storms will occur, it may show how to prevent damage to communication systems, power grids, satellites, and danger to astronauts in space.
- There is some evidence that cycles of solar activity may affect Earth's climate. This problem is very complex, and no one has determined whether this could be an important effect, and if so, what the effects are.
- Finally, when scientists answer one question through their research, they usually create another question in the process!

18. Please think about the activity you did in the Activity Section (the Sunspot white light vs. x-ray active area measuring and data plotting). What did your plot look like? Describe the pattern of points on your graph. As a science investigator, what do you think this means about sunspots and x-ray active areas on the Sun?

Students should be able to describe the graph using the correct terms for measured quantities. For example: "In our graph, x-ray active areas were plotted along the vertical axis and sunspot areas along the horizontal axis. Most of the points fell near a line with a positive (or negative, or flat, or vertical) slope." If the slope seemed nearly flat or vertical, students should note the constant value of x-ray area or sunspot area (respectively) of the line. Students' descriptions of x-ray vs. sunspot area graphs should not mention time dependency. Students should understand that any well-defined systematic pattern in the graph is a sign of some correlation. Only if the points seem randomly scattered would the two quantities not be related. Any of these kinds of observations on the part of the student show understanding of the measurement/plotting/interpretation process. Better answers will have more detailed descriptions and make a logical connection between the plot description and interpretation of any correlation the plot does or does not show.

Plots of area vs. time Give students an appropriate alternative wording for question 18. Descriptions of these plots may include observations about the shapes of the graph and whether graphs of x-ray areas and sunspot areas look alike. Students making both time graphs should draw some conclusion about whether any similarity indicates correlation.