

OpenStax Astronomy, Ch.15: WS Solutions (Apr-2021)

Solutions

1. Describe how energy makes its way from the nuclear core of the Sun to the atmosphere. Include the name of each layer and how energy moves through the layer.

Energy is released as a result of nuclear reactions in the core of the Sun and travels upward (outward) in the form of light. It keeps doing that in the radiative layer, but as the temperature of the layer drops, the energy (wavelength) of the light drops as well. When the energy gets up to the convective layer, energy gets to the surface by moving the hot material of the Sun itself upward. The energy is released at the surface as light, cools the material, and the cooled material sinks back down again.

2. Make a sketch of the Sun's atmosphere showing the locations of the photosphere, chromosphere, and corona. What is the approximate temperature of each of these regions?

The order of the layers from the bottom up is: the photosphere (5800 K), the chromosphere (10,000 K), and the corona (1,000,000 K).

3. Why do sunspots look dark?

Sunspots appear dark because they are cooler than the surrounding area of the Sun.

4. Which aspects of the Sun's activity cycle have a period of about 11 years? Which vary during intervals of about 22 years?

The number of sunspots goes from very few (maybe none) to about one hundred at one time (maximum) and back to very few (minimum) in cycles ranging from 9 to 14 years. During each cycle, the north or south magnetic pole of the sunspots leads. In the next cycle, the polarity reverses. So the overall magnetic activity of the Sun has an average cycle of 22 years.

5. Summarize the evidence indicating that over several hundreds of years or more there have been variations in the level of the solar activity.

Counts of sunspots infer the overall magnetic field changes, which correlate with the level of the magnitude of the solar dynamo and hence solar activity. Astronomers have reliable data going back to 1750.

6. What is the Zeeman effect and what does it tell us about the Sun?

The Zeeman effect is the splitting of spectral lines into several closely spaced lines due to the presence of a sunspot's magnetic field. The magnitude of the splitting tells us the strength of the local magnetic field on the Sun.

7. Compare and contrast the four different types of solar activity above the photosphere.

Plages are regions of higher density and temperature than the surrounding material in the chromosphere. Prominences are huge loops of the Sun's ionized but cool material that are gently pushed by magnetic force from the chromosphere into the corona. Flares are brief, violent explosions that are hot and release a lot of energy. Coronal mass ejections happen when a flare is so violent that the flare material exceeds the escape velocity of the Sun and is ejected out into the solar system. All of these are physically related to sunspots.

8. What are the two sources of particles coming from the Sun that cause space weather? How are they different?

The Sun constantly throws off particles from the surface called the solar wind; this is constant and predictable over hundreds of years. The solar activity cycle can generate solar storms from coronal mass ejections, which are violent and hard to predict.

9. How does activity on the Sun affect human technology on Earth and in the rest of the solar system?

Solar activity can affect satellite orbits, communication satellites, and the local power grids. It can also impact our spacecraft throughout the solar system, especially orbiters or landers on surfaces without an atmosphere.

10. How does activity on the Sun affect natural phenomena on Earth?

Solar activity can affect the aurora, weather, and climate.

11. How can the prominences, which are so big and 'float' in the corona, stay gravitationally attached to the Sun while flares can escape?

The material has to achieve or exceed escape velocity from the Sun. Energetic flares can reach high enough speeds to escape (about 600 km/s), but the prominences do not.

12. If you were concerned about space weather and wanted to avoid it, where would be the safest place on Earth for you to live?

The safest place to live on Earth would be on the equator in a valley. Earth's magnetic field deflects the charged particles ejected by the Sun onto the magnetic poles of Earth. Those are currently located in high and low (extreme northern and southern) latitudes, so the equator would be the safest place. Earth's atmosphere absorbs at least some of the energy, so a lower elevation would also be safer.

13. Suppose you live in northern Canada and an extremely strong flare is reported on the Sun. What precautions might you take? What might be a positive result?

A strong flare may signal the ejection of charged particles from the Sun that can interfere with the operation of power stations and even cause the temporary loss of power on Earth. It might be appropriate to stock some candles, some wood for the fireplace, and some batteries to run devices so you can get information about when power might be restored. Since aurorae are often caused by these same charged particles, you might be treated to a fine display of the northern lights.

14. Assuming an average sunspot cycle of 11 years, how many revolutions does the equator of the Sun make during that one cycle? Do higher latitudes make more or fewer revolutions compared to the equator?

According to the text, the Sun's equator has a period of 25 days. Divide 11 years by 25 days, and convert the units of one of them to find the ratio (no units). Since the higher latitudes have longer periods, they move more slowly and make few revolutions in the same cycle: $11 \text{ y}/25 \text{ d} \times 365 \text{ d/y} = 161 \text{ revolutions}$.

