PHYS#215 - CH#10 - Q & A

Monday, April 26, 2021 9:25 AM

Concept Review

The everyday layer ("surface") of the **quiet Sun** we see is the **photosphere**; phenomena in it that appear nonuniformly and change with time are signs of the **active Sun**. Beneath it is the solar **interior**, with the energy generated at the solar **core**, whose temperature is about 15 million kelvins (Section 10.1). The **solar atmosphere** above the photosphere contains the pinkish **chromosphere** and the white **corona**. The corona expands into space as the **solar wind**, a stream of particles that bathes Earth.

The Sun's photosphere, observed in all the visible light together (which is known as **white light**), is covered with tiny **granulation** (Section 10.1a). Each granule is a pocket of rising hot gas or falling cool gas driven by the process of **convection**, which is similar to water boiling. Oscillations (vibrations) of the surface reveal conditions in the solar interior; the study of the Sun in this manner is called **helioseismology** by analogy with Earth seismology. The spectrum of the photosphere shows a multitude of Fraunhofer (absorption) lines; as with other normal stars, it does not produce emission lines.

The Sun's chromosphere is a very thin layer, somewhat hotter than the photosphere below it (Section 10.1b). It consists of many **spicules**, which are jets of gas that rise and fall, and it shows an emission-line spectrum instead of absorption lines, since the gas is silhouetted against the dark sky rather than against the bright photosphere.

The corona, best seen during total solar eclipses, contains gas with a temperature of 2 million kelvins (Section 10.1c); thus, it is actually a plasma, consisting of positively and negatively charged particles, and it produces emission lines. The magnetic field shapes the coronal gas into **streamers**. Regions where the corona is less dense and cooler than average are **coronal holes**. The slow solar wind is a general coronal expansion, and the fast solar wind comes from coronal holes. Although instruments on spacecraft can be used to block the photosphere, some chromospheric and coronal phenomena are still best observed from the ground during solar eclipses (Section 10.1d).

Sunspots are regions in the photosphere with strong, tangled magnetic fields and are cooler than the surrounding photosphere; the magnetic fields inhibit the rise of hot, ionized gases from beneath the sunspot (Section 10.2a). Each sunspot has a dark **umbra** surrounded by a lighter **penumbra**. Sunspots usually appear in pairs having a north pole, a south pole, and **magnetic-field lines** linking them; these pairs are often in larger groups.

The **solar-activity cycle**, including the **sunspot cycle**, lasts about 11 years (or about 22 years, if magnetic polarity is included); the average number of sunspots periodically rises and falls (Section 10.2b). The **Maunder minimum** was a seventeenth- and eighteenth-century period when sunspots were essentially absent. The last solar maximum was in 2012−2015 and was weaker than average.

Solar flares and **coronal mass ejections** are eruptions of tremendous amounts of energy (Section 10.2c). Electromagnetic radiation and particles from flares can disrupt radio communications or produce electrical surges, affecting satellites and leading to blackouts of electricity. The study of **space weather** – the effect of the Sun on interplanetary space and Earth – has increasing importance. **Prominences** are pinkish protrusions off the edge of the Sun and can be seen during total solar eclipses; when viewed in silhouette on the face of the Sun, they appear as relatively dark **filaments** (Section 10.2d). Sun-pointing telescopes on the GOES weather satellites continuously monitor the solar atmosphere at various wavelengths (Section 10.2e).

In 1905, Albert Einstein published five very important papers, including two on the **special theory of relativity**, which assumes that the speed of light is an important constant that cannot be exceeded by real objects moving through space (Section 10.3). In 1916, Einstein published his new theory of gravity, the **general theory of relativity**; mass and energy are understood to warp (curve) space and time, and objects move freely within this curved space-time. Some basic tests of this theory involved the large mass of the Sun. Specifically, it was verified that the Sun's mass affects the orbit of Mercury; the perihelion (point of closest approach to the Sun) rotates, or precesses, slowly with time, showing the changing orientation of Mercury’s elliptical orbit. Observational verification (during a total solar eclipse) that the Sun bends starlight passing near it, as predicted by Einstein, instantly made him world famous. The recent detections of merging black holes and neutron stars by the gravitational radiation they emit, with the Laser Interferometer Gravitational-wave Observatory (LIGO), is leading to extensive searches for optical counterparts; the field is one of the hottest in modern-day astronomy.

Questions

1. Sketch the Sun, labeling the interior, the photosphere, the chromosphere, the corona, sunspots, and prominences.

2. Draw a graph showing the Sun's approximate temperatures, starting with the core and going upward through the corona.

3. Define and contrast a prominence and a filament.

4. Why are we on Earth particularly interested in coronal holes?

5. List three phenomena that vary with the solar-activity cycle.

6. Discuss what can be learned from studies of the vibration (oscillation) of the Sun's atmosphere.

7. Why can't we observe the corona every day from Earth's surface?

8. How do we know that the corona is hot?

9. If the corona is so much hotter than the photosphere, why isn't it much brighter than the photosphere, per unit area?

10. Describe relative advantages of ground-based eclipse studies and of satellite studies of the corona.

11. What is the process of convection? Give an example in everyday life.

12. Describe the sunspot cycle.

13. Why do we say that the true solar-activity cycle actually has a period of 22 years, rather than 11 years?

†14. Large groups of sunspots can be relatively long-lived (a few months), and they remain essentially fixed at the same physical location on the photosphere throughout their lives. Suppose a sunspot group appears to move from the center to the edge (limb) of the Sun’s disk in 7 days. What is the approximate rotation period of the Sun? (A rough estimate will suffice; don’t worry about not being able to see the sunspot if it is exactly at the edge of the Sun.)

†15. (a) From the table in *A Closer Look 10.1: The Most Common Elements in the Sun’s Photosphere*, calculate the percentage (by number) of helium atoms in the Sun and the percentage of iron atoms. **(b)** Calculate the percentage of mass taken up by helium atoms and by iron atoms.

16. What are solar flares and coronal mass ejections?

17. What feature in the corona shows the magnetic field there?

18. What are two ways that the Sun’s corona can be studied from the Solar Dynamics Observatory?

19. What is the difference between the special theory of relativity and the general theory of relativity?

20. Why was the Sun useful for checking the general theory of relativity?

21. Explain in your own words how Einstein's general theory of relativity accounts for the Sun's gravity.

22. True **or false?** The hottest region of the entire Sun is the core, even though the corona emits profusely at x-ray wavelengths.

23. True **or false?** During times of sunspot maximum, an unusually large number of prominences, solar flares, and coronal mass ejections also occur on the Sun.

24. True or false**?** It is safe and easy to view sunspots on a bright sunny day with the naked eye, without filters or other equipment.

25. True **or false?** If we can see more sunspots and prominences than usual, it is likely there will be more auroral activity seen on Earth.

26. True **or false?** In principle, there could have been a total lunar eclipse visible from Earth one week after the August 21, 2017, total solar eclipse (regardless of whether there actually was one).

27. True **or false?** According to Einstein's general theory of relativity, mass causes the surrounding space-time to curve.

28. True or false**?** If a dark sunspot could be viewed alone, without the glare of the surrounding photosphere, it would still appear quite dark because it emits very little light.

29. True or false? The "solar wind" coming from the Sun consists mostly of photons, and they can interact with Earth's magnetic field.

30. True or false? The solar activity cycle has a period of about 22 years, including the magnetic pole reversal.

31. True or false? The Sun's corona can typically be seen by blocking our view of the Sun's photosphere, for example, with a coin.

32. True or false? The temperature of the Sun decreases from its core to the photosphere, and out through the corona.

33. True or false? Observations of a previously unobserved phenomenon made during a total solar eclipse provided the first verification of a new prediction of Einstein's general theory of relativity.

34 Multiple choice: Sunspots appear dark because **(a)** they are patches of the photosphere that occasionally burn up, creating soot; **(b)** the changing magnetic polarity of the Sun causes gas in the sunspot to cool down substantially; **(c)** they are regions in which strong magnetic fields make it difficult for fresh supplies of hot, ionized gas to reach the photosphere; **(d)** they are much hotter than the surrounding area, so their emission peaks at ultraviolet wavelengths, which our eyes cannot see; or **(e)** they are holes in the photosphere through which the cooler interior of the Sun is visible.

35. Multiple choice: Which one of the following is *not* influenced by the Sun's magnetic field? **(a)** Solar prominences. **(b)** Sunspots. **(c)** Solar flares. **(d)** Prominences and filaments. **(e)** The Sun's blackbody spectrum.

36. Multiple choice: As the solar atmosphere expands outward from the Sun, into interplanetary space, it becomes the **(a)** chromosphere; **(b)** corona; **(c)** spicules; **(d)** prominences; or **(e)** solar wind.

37. Multiple choice: Which one of the following statements about our Sun is *true*? **(a)** The Sun consists primarily of hydrogen and helium. **(b)** The Sun is a very active star, blasting waves of energy, solar flares, and winds continuously and uniformly with time. **(c)** The apparent motion of sunspots on the Sun is caused mainly by Earth's orbit. **(d)** Being an uncharged (i.e., neutral) star, the Sun does not have a significant magnetic field. **(e)** Sunspots were first discovered recently, using telescopes in space.

38. Multiple choice: Suppose the temperature of a sunspot is 4000 K and that of the surrounding photosphere is about 6000 K. What is the ratio (sunspot to photosphere) of the wavelengths at which the roughly blackbody spectra are brightest? (Hint: See Chapter 2.) **(a)** . **(b)** . **(c)** $()^2$. **(d)** 3. **(e)** 2000.
3/2

†39. Multiple choice: Suppose the temperature of a sunspot is 4000 K and that of the surrounding photosphere is about

6000 K. Per unit area, about how much energy per second does the sunspot emit, compared with the photosphere? (Hint: see Chapter 2.) **(a)** . **(b)** . **(c)** 2000. **(d)** $()^2$. **(e)** $()^4$.

(2/3)^4

40. Multiple choice: Which one of the following statements about our Sun is *true*? **(a)** Being farther from the center of the Sun, the chromosphere has a lower temperature than the photosphere. **(b)** Sunspots appear dark because there isn't any nuclear fusion occurring in them, unlike the case in the surrounding photosphere. **(c)** The chromosphere appears reddish pink because it reflects Hα emission from the photosphere. **(d)** Coronal mass ejections occur when the nuclear-fusion rate in the Sun suddenly increases by a large amount. **(e)** The Sun's rotation period can be determined by tracking the positions of long-lived sunspots.

41. Multiple choice: Which one of the following does *not* change during the course of one full 22-year solar activity cycle? **(a)** The frequency of sunspots. **(b)** The Sun's overall magnetic field orientation. **(c)** The Sun's rotation speed. **(d)** The frequency of coronal mass ejections. **(e)** The frequency of prominences and flares.

†42. Multiple choice: If you observe a sunspot whose diameter is about that of the Sun, it is roughly _____ times the diameter of Earth. **(a)** . **(b)** . **(c)** 1. **(d)** 5. **(e)** 20.

43. Multiple choice: The Sun doesn't have a perfect blackbody spectrum because **(a)** its spectrum consists of emission lines of the elements in the Sun, so there are some gaps; **(b)** its core is much hotter than its surface, so the shape of the curve is distorted; **(c)** the coronal mass ejections interfere with the photons, adding too much noise to the spectrum; **(d)** the Sun is too hot to radiate at all wavelengths; or **(e)** the relatively cool outer layers absorb photons emitted in the hot inner parts of the Sun, producing absorption lines.

44. Fill in the blank: During a total solar eclipse, stars near the Sun's edge are observed to be a bit Farther from ________ the Sun than they would have been had the Sun not been present, in the amount predicted by Einstein's general theory of relativity.

45. Fill in the blank: In the few days after a powerful solar flare, we might expect to see aurora _______ at night in Earth's atmosphere.

46. Fill in the blank: By far the most abundant element in the Sun is Hydrogen _________.

47. Fill in the blank: The Sun's color, when it is high in the sky and there isn't much pollution, is White _______.

48. Fill in the blank: The gradual Advance of Perihelion ______ of Mercury's orbit provided one test of Einstein's general theory of relativity.

49. Fill in the blank: The SOHO ______ satellite allows us to obtain three-dimensional views of coronal mass ejections and other phenomena, even on the far side of the Sun. †This question requires a numerical solution.