9.10: The Sun- A Nuclear Powerhouse (Exercises)

For Further Exploration

Articles

Harvey, J. et al. “GONG: To See Inside Our Sun.” *Sky & Telescope* (November 1987): 470.

Hathaway, D. “Journey to the Heart of the Sun.” *Astronomy* (January 1995): 38.

Kennedy, J. “GONG: Probing the Sun’s Hidden Heart.” *Sky & Telescope* (October 1996): 20. A discussion on hydroseismology.

LoPresto, J. “Looking Inside the Sun.” *Astronomy* (March 1989): 20. A discussion on hydroseismology.

McDonald, A. et al. “Solving the Solar Neutrino Problem.” *Scientific American* (April 2003): 40. A discussion on how underground experiments with neutrino detectors helped explain the seeming absence of neutrinos from the Sun.

Trefil, J. “How Stars Shine.” *Astronomy* (January 1998): 56.

Websites

Albert Einstein Online: http://www.westegg.com/einstein/.

Ghost Particle: http://www.pbs.org/wgbh/nova/neutrino/.

GONG Project Site: http://gong.nso.edu/.

Helioseismology: solar-center.stanford.edu/abo...eismology.html.

Princeton Plasma Physics Lab: http://www.pppl.gov/.

Solving the Mystery of the Solar Neutrinos: www.nobelprize.org/nobel_priz...ysics/bahcall/.

Videos

Deep Secrets of the Neutrino: Physics Underground: https://www.youtube.com/watch?v=Ar9ydagYkYg. 2010 Public Lecture by Peter Rowson at the Stanford Linear Accelerator Center (1:22:00).

The Elusive Neutrino and the Nature of Physics: https://www.youtube.com/watch?v=CBfUHzkcaHQ. Panel at the 2014 World Science Festival (1:30:00).

Review Questions

1. How do we know the age of the Sun?
2. Explain how we know that the Sun’s energy is not supplied either by chemical burning, as in fires here on Earth, or by gravitational contraction (shrinking).
3. What is the ultimate source of energy that makes the Sun shine?
4. How is a neutrino different from a neutron? List all the ways you can think of.
5. Describe in your own words what is meant by the statement that the Sun is in hydrostatic equilibrium.
6. Two astronomy students travel to South Dakota. One stands on Earth’s surface and enjoys some sunshine. At the same time, the other descends into a gold mine where neutrinos are detected, arriving in time to detect the creation of a new radioactive argon nucleus. Although the photon at the surface and the neutrinos in the mine arrive at the same time, they have had very different histories. Describe the differences.
7. What do measurements of the number of neutrinos emitted by the Sun tell us about conditions deep in the solar interior?
8. Do neutrinos have mass? Describe how the answer to this question has changed over time and why.
9. Neutrinos produced in the core of the Sun carry energy to its exterior. Is the mechanism for this energy transport conduction, convection, or radiation?
10. Describe the two main ways that energy travels through the Sun.

Thought Questions

1. Someone suggests that astronomers build a special gamma-ray detector to detect gamma rays produced during the proton-proton chain in the core of the Sun, just like they built a neutrino detector. Explain why this would be a fruitless effort.

2. A friend who has not had the benefit of an astronomy course suggests that the Sun must be full of burning coal to shine as brightly as it does. List as many arguments as you can against this hypothesis.
3. Earth's atmosphere is in hydrostatic equilibrium. What this means is that the pressure at any point in the atmosphere must be high enough to support the weight of air above it. How would you expect the pressure on Mt. Everest to differ from the pressure in your classroom? Explain why.
4. Explain what it means when we say that Earth's oceans are in hydrostatic equilibrium. Now suppose you are a scuba diver. Would you expect the pressure to increase or decrease as you dive below the surface to a depth of 200 feet? Why?
5. Suppose you are standing a few feet away from a bonfire on a cold fall evening. Your face begins to feel hot. What is the mechanism that transfers heat from the fire to your face? (Hint: Is the air between you and the fire hotter or cooler than your face?)
6. Give some everyday examples of the transport of heat by convection and by radiation.
7. Do you think that nuclear fusion takes place in the atmospheres of stars? Why or why not?
8. Explain how mathematical computer models allow us to understand what is going on inside of the Sun.
