Index Card, Sep. 6

This is a "practice question" for next Thursday's quiz. It will be graded only for participation, but correct and incorrect responses will be posted:

Compare how a photon versus a neutrino, both created during nuclear fusion reactions in the Sun's core, travel to the solar surface. (Original metaphors are welcome, but not required.)

Which travels faster, the photon or the neutrino? Which gives us the most up-to-date information about conditions in the Sun's core?

Ingredients of a Full-Credit Answer

"Compare how photons vs. neutrinos, both made in the Sun's core, travel to the solar surface."

For full credit, your answer needed to either *say* or *describe* the indirect "random walk" that a photon created in the core goes through, in order to get from there to the Sun's surface. The video we saw on 9/4 used the metaphor of a person at a party trying to get across a room, having to repeatedly stop and greet someone before moving on. The neutrino, however, passes directly through the Sun's interior without pausing along the way.

Sample Correct Responses

- "Photons travel through the Sun's radiative zone in a 'random walk,' being absorbed and re-emitted by atoms ~~constantly~~ [better: repeatedly] until they escape the Sun's surface. Neutrinos travel though the Sun and reach the Earth in a little over 8 minutes."
- "Photons ricochet from particle to particle in the Sun's thickest layer .. neutrinos travel through the Sun with ease. It's because of this that the neutrino ***is faster in reaching us***, and therefore gives us our most up-to-date information."

Alternate Examples

- "Neutrinos do not react with matter, so to them the Sun is transparent. Photons & neutrinos travel at [nearly] the same speed, but *neutrinos travel further faster*."
- "A photon meanders like an old man in a park, feeding pigeons, bouncing between benches and flocks of birds."
- "A photon does not '~~travel to~~' [travel ***directly*** to] the surface; it ends up there after taking many side trips, ≈ 100,000 years' worth of side trips."

Some Confusions (Red = Wrong)

- "A photon bounces from helium grouping to helium grouping [no, photons are not absorbed only by He; most of the particles doing the absorbing are protons (= H nuclei) or electrons].
- "A neutrino has so little mass and such high energy that it doesn't interact with matter." This reasoning is not correct. The photons initially made in fusion also have high energies, and they have **zero** mass, yet *they* interact with matter. The reason neutrinos don't interact is because they are different kind of beast.

Some Confusions (Red = Wrong)

- "Neutrinos give us the most up-to-date info about the Sun's core because neutrinos have really big mass. It can be detected easier than photons." Both statements are **wrong**. Neutrinos have very small masses (physicists are still working on measuring them), and they are *vastly* more difficult to detect than are photons.
- "Photons change into neutrinos and vice versa." No, definitely not! Neutrinos change from one type of neutrino into another, but they don't change into photons!

Did You Read the Question?

- "A photon is from the outer surface of the Sun, but a neutrino comes from its core." The question *says* to consider photons created in the core.
- "During nuclear fusion, photons are released.. When the protons ~~attract~~ [no, fuse], they are lighter in terms of mass and this is released as a photon." This is not what we asked about.
- "Gravity attempts to bring everything into the core while pressure tries to exert force outwards making the Sun almost perfectly balanced." Again, this may be correct, but it's not relevant!

(Not) Answering the Question

•You will not get credit for a response that may be true but has *nothing to do* with the question.

•I am testing you not only on whether you can answer the question correctly, but whether you know what is ***and what isn't*** relevant.

•So, do not simply spill everything you know that is remotely related to the topic (otherwise known as a "data dump" or "fishing expedition"). This is likely to lead to your losing credit!

Confusion about Basics

- "Neutrinos travel faster than photons, at the speed of light … because neutrinos are weak and low mass, they travel at nearly the speed of light, faster than photons." *Of course* photons travel at the speed of light; photons ***are*** light!
- "A photon is classified as antimatter (e^+)." Nope, you're thinking of a *positron*. There are a lot of "look-alike" terms among subatomic particles; make sure you know the differences:
  - Photon, proton, positron
  - Neutron, neutrino

Confusion about Basics

- "Photons have a hard time moving through the ~~radioactive~~ [no, radiative] zone." It's called the radiative zone because energy passing through it is carried by photons = radiation.
- "A photon travels to [no, from!] the Sun's core through inverse β-decay. The formula is: $p^+ \rightarrow n + e^+ + \nu$. A neutrino travels to the surface as the equation …" It sounds like you think the arrow means motion (traveling). No! The arrow indicates a reaction, the left side is converted into what's on the right, just like in chemistry.

What Meaning of "Faster" Here?

Which travels faster, the photon or the neutrino?

•The question "which travels faster" is subtle.

•The photon moves at a (slightly) faster **speed** than the neutrino *over short distances*.

•However, in getting from the core to the surface, both speed ***and direction*** matter. Because the neutrino moves directly, a "straight shot" out of the Sun, while the photon takes a sometimes back-tracking "convoluted" path, the neutrino takes much less time to emerge from the Sun.

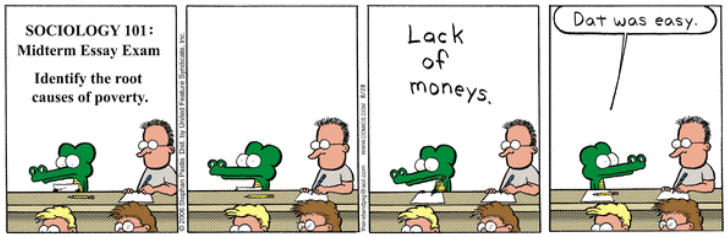
Last Part of the Question

Which gives us the most up-to-date information?

•The question is about photons and neutrinos, so the answer is not "helioseismology" or "SNO."

•By "up-to-date" we mean what is going on in the Sun's core *right now*. The neutrinos were made a mere few minutes ago. The photons we see today started out in the Sun's core over 100,000 years ago; they are "stale," outdated. Consider: if the fusion reactions suddenly stopped in the Sun right now, how long would it take for us to know it, from the neutrinos? From the photons?

Advice on Answering Essay Questions



Advice on Answering Essay Questions

- **DON'T** simply restate the question in another way. This will not earn you any credit.
- **DON'T** skim the question hastily, notice some word or phrase and assume that you know what the question is about.
- **DON'T** use the "kitchen sink" approach, doing a data dump of everything that might conceivably be relevant and hoping to include the correct answer by accident. (It's really obvious if you do this.)
- **DON'T** write vague statements with no real content. You cannot "bluff" on astronomy tests!

Advice on Answering Essay Questions

- **DO** read the question carefully. *Make sure* you know what is being asked.
- There is some key idea or insight I'm looking for; see if you can figure out what it is.
- If I give a hint, think hard about it. I'm trying to steer your thinking in a particular direction.
- One you've grasped the basic point, write the answer clearly and concisely.
- If a sketch would make your response clearer, draw it and label it clearly.