Answers to the Sun Assignment – Milligan's Astronomy

1. Mass of Sun is 330000 times the Earth so Earth is to Sun as one person is to 3 Neyland Stadiums full of people. Jupiter is 318 times Earth, so Jupiter like a few hundred people, say all of the players, coaches, etc. that are actually on the field at a football game.
2. **Core** is the part of the Sun where fusion occurs. The **radiation zone** is where EMR from the core moves outward. The **convection zone** is where hot materials (less dense) rise and cool materials (more dense) fall causing circulation within the Sun. The **photosphere** is the "surface of the Sun" – a narrow region that emits visible light that escapes into space. The **chromosphere** is the coolest part of the Sun, immediately above the photosphere and has a reddish appearance. The **transition zone** is where the temperature begins to increase after having fallen going outward from the center of the Sun. The **corona** is the "crown like" outer atmosphere of the Sun that is visible during a total eclipse. The **solar wind** is a steady stream of particles (ions) escaping the Sun and flying out into space in all directions.
3. Coolest = Chromosphere, 4500 K: hottest = Core, 15 million K: photosphere = 5800 K.
4. Wein's Law: $\lambda = 0.29/T$ (a) $\lambda = 0.29/10000000 = 2.9 \times 10^{-8}$ cm $= 2.9 \times 10^{-10}$ m (X-ray) (b) repeat with 100000 K: $\lambda = 2.9 \times 10^{-8}$ m (UV) (c) repeat with 10000 K: $\lambda = 2.9 \times 10^{-7}$ m (UV) (d) repeat with 1000000 K: $\lambda = 2.9 \times 10^{-9}$ m (X-ray)
5. Granules are evidence of convection – the brighter center of a granule represents hot materials rising to the surface and the dimmer edges of a granule represent cooler materials falling.
6. The sharp "edge" of the Sun is due to the fact that only a relatively small region emits the vast majority of the visible light that escapes into space and can be seen from Earth.
7. Coronium is the name given to an initially unknown substance thought to exist in the corona evidenced by unique spectral lines. Eventually scientists determined that the lines were actually coming from highly ionized iron atoms that exist in the corona. This helped scientists determine the temperature of the corona.
8. The solar wind is a steady stream of particles (ions) escaping the Sun and flying out into space in all directions.
9. Helioseismology is the study of sound-like waves that travel through the Sun. Based on these waves scientists can determine properties such as density, temperature, etc. In a similar fashion scientists use seismic waves to study the interior of Earth. Waves in Earth are generated by earthquakes and shifting of tectonic plates whereas waves in the Sun are generated by activity such as flares and coronal mass ejections.
10. Speed = distance per time. Speed = 2*diameter/period = $2*(1.39 \times 10^9$ m$)/300$ s $= 9.3 \times 10^6$ m/s. Now compare this speed to that of sound on earth: $9.3 \times 10^6 \div 343 = 27000$ times faster than the speed of sound in air.
11. In the core of the Sun mass is converted to gamma radiation by fusion reactions according to $E = mc^2$. This gamma travels outward through the radiation zone, being absorbed and reemitted by atoms along the way. At the bottom of the convection zone gamma radiation is absorbed, heating the material found there. This hotter less dense material rises to the surface by the process of convection. At the surface or photosphere visible light is emitted into space by blackbody radiation. This light travels unimpeded through space to the Earth.

12. When fusion reactions occur the mass of the products is less than the mass of the reactants. This "missing mass" is "converted" to energy by the equation $E = mc^2$. Because such a large amount of energy is given off by conversion of a relatively small amount of mass the Sun can last for a very long time. It has an extremely huge mass to begin with and a tiny fraction of this is "consumed" in a year.
13. $E = mc^2$: 3.85×10^{26} J = m*$(3 \times 10^8$ m/s$)^2$, $m = 4.28 \times 10^9$ kg = mass converted per second.
14. 4.28×10^9 kg ÷ 900000 kg = 4800; The rate of destruction of mass by nuclear fusion is 4800 times greater than loss of mass into space due to the solar wind.
15. (a) rate = amount/time; time = amt/rate; time = mass of sun/rate of loss; $t = 1.99 \times 10^{30}$ kg/$(4.28 \times 10^9 + 900000$ kg/s$) = 4.65 \times 10^{20}$ s $= 1.5 \times 10^{13}$ yrs
(b) These rates of mass loss cannot be constant because the proton-proton chain can only procede as long as there is hydrogen in the Sun.
16. Proton-proton chain begins with 6 protons and 6 electrons (*i.e.* 6 hydrogen atoms) and ends with 1 helium nucleus, 2 neutrinos, 2 protons, and 4 electrons (*i.e.* 1 helium atom, 2 hydrogen atoms, and 2 neutrinos).
17. Amount of hydrogen = 71 % = $0.71(1.99 \times 10^{30}$ kg$) = 1.41 \times 10^{30}$ kg. Conversion of 1 kg of hydrogen releases 6.4×10^{14} J. Total energy released per second = luminosity = 3.85×10^{26} J/s. Divide: 3.85×10^{26} J/s ÷ 6.4×10^{14} J/kg = 6.01×10^{11} kg/s converted. Time to convert all hydrogen into helium: time = amt/rate, t = 1.41×10^{30} kg/ 6.01×10^{11} kg/s = 2.35×10^{18} s = 75 trillion years. (Note: the Sun will not last nearly this long because drastic changes will occur before <u>all</u> of its hydrogen converts to helium.)
18. (a) Neutrinos released during fusion reactions that occur in the core of the Sun can pass through the Sun and travel to Earth. (b) By counting neutrinos detected on Earth scientists can determine rate at which reactions are occurring and compare to theories about those reactions.
19. Divide: $(3.85 \times 10^{26}$ J/s$) \div (4.3 \times 10^{-12}$ J/set of reactions$) = 8.95 \times 10^{37}$ sets/second. However each set of reactions produces 2 neutrinos, so double this to get 1.79×10^{38} neutrinos produced each second.
20. The sun's rotation and convection acts like a "dynamo" or electrical currents (moving charged particles) that produce the Sun's magnetic field. The differential rotation contorts this field over the course of an eleven year cycle. Changes in the magnetic field are responsible for the active phenomena of the Sun.
21. Sunspots occur in pairs when a part of the Sun's magnetic field protrudes from the surface of the Sun, arcing from one sunspot to another. The field accelerates heated particles which causes the sunspots to cool to a lower temperature.
22. Sunspots during each successive maxima have the opposite magnetic polarity of sunspots that occurred during the previous maxima. This means the the sun has an eleven year cycle of sunspots and a longer twenty-two year cycle of magnetic properties – the sunspot cycle and the solar magnetic cycle.
23. (a) Equator period = 25.1 days, pole period = 36 days. Let x = number of rotations at the pole. Then $(x + 1)$ = number of rotations at the equator (after it has "lapped" the pole one time). Total time that has passed = number of laps times the period. Therefore set times at each location equal to one another: $x(36) = (x + 1)(25.1)$ Then solve for x to get $x = 2.3$ (and $x + 1 = 3.3$). Time that has passed = 2.3(36 days) = 3.3(25.1 days) = 82.9 days. (b) 11 years = 4018 days. 4018 ÷ 82.9 = 48 times