

Introductory Astronomy

Homework 8: The Sun Not to be handed in. Homework solutions are posted already.

- The diameter of the Sun is about:
 - 1 Earth diameter,
 - 30 Earth diameters,
 - 109 Earth diameters,
 - 1 astronomical unit,
 - 1 light-year.
- The solar luminosity is L_{\odot} =:
 - 100 W.
 - 3.86×10^{-26} W.
 - 3.86×10^{26} W.
 - 1.496×10^{11} m.
 - 6.9599×10^8 m.
- The temperature of the solar photosphere is about:
 - 300 K.
 - 600 K.
 - 273 K.
 - 40000 K.
 - 6000 K.
- The temperature at the center of the Sun is about:
 - 16×10^6 K as known from modeling.
 - 16×10^6 K as known from direct measurement.
 - 273 K.
 - 6000 K as known from modeling.
 - 6000 K as known from direct measurement.
- The solar constant (i.e., the electromagnetic radiation energy per unit time per unit area from the Sun at the top of the Earth's atmosphere) is
 - 1367 W/m².
 - 1000.00 W/m².
 - 0.
 - 1367 W/m².
 - infinite.
- The solar constant (i.e., the electromagnetic radiation energy per unit time per unit area from the Sun at the top of the Earth's atmosphere) is about 1367 watts per square meter. If one had a square kilometer of solar panels (of 100 % efficiency), how many 100 watt light bulbs could you run on solar power assuming no loss due to atmospheric absorption or reflection?
 - 100 watts.
 - 1000.
 - 1367.
 - 1.37×10^{11} .
 - 1.37×10^7 .
- “Let’s play *Jeopardy!* For \$100, the answer is: This astrophysical body has three main interior layers: 1) a core (in which thermonuclear reactions occur) that extends out to about 25 % of the body’s radius; 2) a radiative transfer zone which extends out to about 71 % of the body’s radius; 3) a convective zone that extends from about 71 % of the body’s radius to the body’s surface.”
 What is _____, Alex.
 - the Moon
 - Venus
 - the Milky Way
 - the Earth
 - the Sun
- Out to about 71 % of the Sun’s radius, the dominant energy transfer mechanism is:
 - electron conduction.
 - neutrino transfer.
 - radiative transfer (i.e., transfer by electromagnetic radiation).
 - convection.
 - an explosive shock wave.
- A granule is:
 - a kind of cereal.
 - a grain of dust.
 - the top of a rising current of **HOT** gas in the Sun. Granules are seen in the solar photosphere. They last about 10 minutes and then lose their identity with their surroundings. The risen gas **COOLS** and then sinks.

- d) the top of a rising current of **COLD** gas in the Sun. Granules are seen in the solar photosphere. They last about 10 minutes and then lose their identity with their surroundings. The risen gas **HEATS** up and then sinks.
- e) a solar flare by another name.
10. The five outermost layers of the Sun (defining layers of the Sun generously) can be labeled:
- convection zone, photon, chromosome, coronation street, and solar sail.
 - convection zone, photosphere, chromosphere, corona, and solar sail.
 - convection zone, photosphere, chromosphere, corona, and solar wind.
 - convection zone, photon, chromosome, corona, and glabron.
 - construction zone, photosphere, chromosphere, corona, and glabron.
11. Two of the five outermost layers of the Sun (defining layers of the Sun generously) are:
- photosphere and chromosphere.
 - carnation and corona.
 - corona and paloma.
 - rio and sands.
 - chromosphere and Asteroid Belt.
12. The corona of the Sun is only visible to the unaided eye:
- at sunset.
 - when the Moon is a crescent in the western sky.
 - during partial solar eclipses.
 - during total solar eclipses.
 - when the Sun is below the horizon.
13. The solar wind is:
- the air that blows off the northern hemisphere oceans during geomagnetic storms.
 - the plasma gas that cools the Sun's photosphere.
 - an optical illusion in the corona that causes the corona to look like fluffy orange clouds.
 - the plasma gas that streams from the Sun out into **INTERSTELLAR SPACE**.
 - the plasma gas that streams from the Sun out into **INTERGALACTIC SPACE**.
14. The solar wind is a stream of particles that moves approximately along radial paths outward from the Sun: inward is the negative direction and positive is the outward direction. The solar wind near the Earth is typically moving at a radial velocity of about:
- 200 km/s.
 - 200 m/s.
 - 200 cm/s.
 - 400 to 500 km/s
 - 400 to 500 km.
15. The Sun loses mass at a rate of about 2×10^9 kg/s. Convert this rate into solar masses per year to the same accuracy as given. **NOTE:** The mass of the Sun is $M_{\odot} = 1.9891 \times 10^{30}$ kg and the length of a year in seconds to 0.5% accuracy is $\pi \times 10^7$ s.
- 2×10^{30} kg/yr.
 - $2 \times 10^{-30} M_{\odot}/\text{yr}$.
 - $2 \times 10^9 M_{\odot}/\text{yr}$.
 - $3 \times 10^{14} M_{\odot}/\text{yr}$.
 - $3 \times 10^{-14} M_{\odot}/\text{yr}$.
16. The Sun loses mass at a rate of $\sim 2 \times 10^9 \text{ kg s}^{-1} \sim 3 \times 10^{-14} M_{\odot}/\text{yr}$. (Note that M_{\odot} is the standard symbol for a solar mass: i.e., the mass of the Sun.) If this rate remained constant (which is highly unlikely), how long until the Sun is all gone? (Note a gigayear (Gyr) is a billion years.)
- $\sim 10^{10} \text{ yr} = 10 \text{ Gyr}$.
 - $\sim 10^9 \text{ s}$.
 - $\sim 3 \times 10^{13} \text{ yr} = 3 \times 10^4 \text{ Gyr}$.
 - $\sim 5 \times 10^9 \text{ yr} = 5 \text{ Gyr}$.
 - $\sim 3 \times 10^{13} \text{ s}$.
17. Magnetic fields:
- are caused by **ELECTRIC CURRENTS** (and time varying electric fields) and tend to cause charged particles to **PERAMBULATE**.

- b) are caused by **ELECTRIC CURRENTS** (and time varying electric fields) and tend to cause charged particles to **ACCELERATE** to the speed of light.
 - c) are caused by **HEAT** and tend to cause charged particles to **ACCELERATE** to the speed of light.
 - d) are caused by **ELECTRIC CURRENTS** (and time varying electric fields) and tend to cause charged particles to move in **SPIRALS**.
 - e) are caused by **HEAT** and tend to cause charged particles to move in **SPIRALS**.
18. The Earth's magnetic field:
- a) gives **CONSIDERABLE** protection from the high-energy charged particles in the solar wind.
 - b) gives **NO** protection from the high-energy charged particles in the solar wind.
 - c) gives **CONSIDERABLE** protection from the high-energy charged particles in the solar wind. It also **STOPS** all high-energy electromagnetic radiation from reaching the Earth's surface.
 - d) gives **NO** protection from the high-energy charged particles in the solar wind. But it does **STOP** all high-energy electromagnetic radiation from reaching the Earth's surface.
 - e) is in the green band of the electromagnetic spectrum.
19. The magnetic field of the Sun is caused by
- a) electrical currents inside the Sun.
 - b) blackbody radiation.
 - c) the Doppler effect.
 - d) charged particles undergoing a Doppler shift.
 - e) the aurora.
20. Sunspots are:
- a) dark spots on the Sun's surface.
 - b) bright spots on the Sun's surface.
 - c) never observable.
 - d) larger than the Sun.
 - e) only a theory.
21. The mean length of the full sunspot cycle is:
- a) 22 years.
 - b) 220 years.
 - c) 24 hours.
 - d) 2000 years.
 - e) 8 minutes.
22. Why do solar astrophysicists think the sunspots are caused magnetic field effects?
- a) Because one of the pair of sunspots has a strong magnetic field. The other doesn't, but that **MAY NOT** be a problem with the theory.
 - b) Because one of the pair of sunspots has a strong magnetic field. The other doesn't and that **IS** a problem with the theory.
 - c) Because sunspots emit **BLACKBODY RADIATION** which is caused by magnetic fields. Moreover, all sunspots have **RELATIVELY STRONG MAGNETIC FIELDS**. The fact that sunspots come in pairs strongly suggests that magnetic field lines emerge from one member of a pair and enter the other member.
 - d) Because sunspots emit a **LINE SPECTRUM** which is caused by magnetic fields. Moreover, all sunspots have **RELATIVELY STRONG MAGNETIC FIELDS**. The fact that sunspots come in pairs strongly suggests that magnetic field lines emerge from one member of a pair and enter the other member.
 - e) All sunspots have **RELATIVELY STRONG MAGNETIC FIELDS**. The fact that sunspots come in pairs strongly suggests that magnetic field lines emerge from one member of a pair and enter the other member.
23. "Let's play *Jeopardy!* For \$100, the answer is: These solar activities are arcs of hot gas with temperatures of order 10000 K that rise from the Sun. They can rise in hours and last weeks or months in which case

they are quiescent. Or they can arise eruptively in a few hours and eject matter into space in which case they are eruptive.”

What are _____, Alex.

- a) sunspots b) coronas c) granules d) prominences e) salients

24. “Let’s play *Jeopardy!* For \$100, the answer is: These solar activities are giant explosions from the Sun with energies up to of order 10^{25} J (i.e., 2.5×10^9 megatons of TNT) with temperatures up to 5×10^6 K. They are believed to be caused by magnetic reconnection in which magnetic field energy is rapidly converted to thermal, electromagnetic radiation, and kinetic energy.”

What are _____, Alex.

- a) solar flares b) granules c) granolas d) grains e) gravitons

25. “Let’s play *Jeopardy!* For \$100, the answer is: They are giant bubbles of hot gas ejected from the Sun within the time span of a few hours. If they impact the Earth’s magnetosphere, they can cause magnetic storms and strong auroras.”

What are _____, Alex?

- a) helium atoms b) hydrogen atoms c) granules d) sunspots e) coronal mass ejections

26. In a best-selling novel of a few years ago (unless my source is just making this up), astronauts on the Moon were killed by high-energy protons from a coronal mass ejection (CME) that reached the Moon 8 minutes after the CME was ejected. What was wrong with this plot device?

- a) High-energy protons never hurt anyone.
 b) CMEs always happen near the solar poles and all the particles they eject get directed off in the solar polar direction: they never head toward Earth (or the Moon).
 c) If one divides 8 minutes by the speed of light, one gets 36 hours. Clearly the astronauts could not have been affected until 36 hours after the CME.
 d) If one divides 1 astronomical unit by the the speed of light, one gets 36 hours. Clearly the astronauts could not have been affected until 36 hours after the CME.
 e) Particles with finite mass cannot move at the speed of light. 8 minutes is roughly the travel time for light from the Sun. (If you don’t believe me, divide 1.496×10^{13} cm by 3.00×10^{10} cm/s and see what you get.) The protons couldn’t have gotten to the Moon in 8 minutes or at least not in the exact light travel time. They could do it in a time very close to the exact light travel time if they were super-energetic: such super-energetic solar protons have not been observed. I don’t think the author could have been Larry Niven.

27. The Sun’s surface composition by mass (which approximates the average cosmic composition and is typical of non-ancient stars) is about:

- a) 100 % helium.
 b) 71 % hydrogen, 27 % nitrogen, and 20 % everything else.
 c) 71 % carbon, 27 % nitrogen, and 2 % everything else.
 d) 71 % hydrogen, 27 % nitrogen, and 2 % everything else.
 e) 71 % hydrogen, 27 % helium, and 2 % everything else.

28. The total power of a star (i.e., energy output per unit time) is called:

- a) brightness. b) rightness. c) lightness. d) luminosity. e) incandescence.

29. "Let's play *Jeopardy!* For \$100, the answer is: This is the energy per unit area per unit time **OR** the energy per unit area in some wavelength band **OR** the energy per unit area per unit time per unit wavelength (or frequency) from some light source (e.g., a star or the Sun)."

What is _____, Alex?

- a) fugue b) flow c) luminosity d) light e) flux

30. "Let's play *Jeopardy!* For \$100, the answer is: It is a star that as observed over relatively short times scales (e.g., all of human history) is burning hydrogen to helium in its core at a constant rate and is in hydrostatic equilibrium."

What is a/an _____, Alex?

- a) dense core b) protostar c) pre-main-sequence star d) H II region e) main sequence star

31. For a main sequence star, the energy radiated away as electromagnetic radiation is almost exactly compensated by:

- a) gravitational energy converted to heat energy during rapid collapse. b) neutrinos from space being absorbed by the star. c) energy produced by nuclear burning on the surface. d) energy produced by nuclear burning in the deep interior. e) nothing at all.

32. Atomic nuclei are made up of:

- a) protons and neutrons. b) protons and electrons. c) positrons and electrons.
d) positrons and neutrals. e) ponytrons and nuggets.

33. Nuclei with the same number of protons, but different number of neutrons are _____ of each other.

- a) isochrones b) isobars c) isotopes d) isodopes e) Isoldes

34. "Let's play *Jeopardy!* For \$100, the answer is: These isotopes of hydrogen have 1 and 2 neutrons, respectively."

What are _____, Alex?

- a) uranium-235 (^{235}U) and uranium-238 (^{238}U) b) helium-3 (^3He) and helium-4 (^4He)
c) the deuteronomy (D or ^2H) and trident (T or ^3H) d) the deuteron (D or ^2H) and triton (T or ^3H)
e) carbon (C) and oxygen (O)

35. Nuclei are bound together by:

- a) gravity. b) the electromagnetic force. c) the centrifugal force. d) the weak nuclear force. e) the strong nuclear force.

36. Nuclear fusion is the _____ bonding of nuclei to form _____ nuclei.

- a) chemical; larger b) nuclear; larger c) nuclear; smaller d) chemical; smaller
e) gravitational; smaller

37. In stellar hydrogen fusion to helium, the rest mass energy of the products is _____ less than that of the reactants. The missing rest mass energy went into _____.

- a) 70 %; heat energy b) 170 %; magnetic field energy c) 0.7 %; heat energy d) 70 %;
magnetic field energy e) 0 %; chemical binding energy
38. 1 kg of matter is equivalent to how much energy? Recall that the speed of light is 3.00×10^8 m/s.
a) 8×10^{16} J. b) 9×10^{16} J. c) 9×10^8 J. d) 3×10^8 J. e) 2×10^8 J.
39. The energy emitted as electromagnetic energy from main sequence stars is supplied by the:
a) nuclear burning of helium to hydrogen. b) nuclear burning of hydrogen to helium.
c) nuclear burning of hydrogen to carbon. d) nuclear burning of helium to carbon.
e) chemical burning of hydrogen to carbon.
40. Thermonuclear reactions happen only in a star's core (which for the Sun is the region within about 0.25 solar radii of the Sun's center) because only there is it _____ enough.
a) cold and dilute b) hot and dense c) hot and dilute d) bland and fragile e) dirty and smudgy
41. Why don't thermonuclear reactions happen on the surface of main sequence stars?
a) Not hot and not dense enough. b) Too hot and too dense. c) Too green. d) Too bad. e) Too late.
42. In addition to observations of a star and physics theory, in order to understand the star in detail one needs:
a) a few calculations on a scrap of paper. b) detailed computer modeling. c) experiments on Sun-size gas balls. d) nothing else at all. e) luck.
43. "Let's play *Jeopardy!* For \$100, the answer is: This is a set of calculated distributions of temperature, density, luminosity, and other physical quantities for a star."
What is _____, Alex?
a) the star mass b) the star itself c) a model of the star d) the star luminosity
e) the astronomical unit
44. Hydrostatic equilibrium means that:
a) pressure and other forces in a fluid are **UNBALANCED**, but the fluid is exhibiting a **SMOOTH FLOW** (at least in the reference frame of the fluid center of mass).
b) pressure and other forces in a fluid are **UNBALANCED** and the fluid is exhibiting a **TURBULENT FLOW** (at least in the reference frame of the fluid center of mass).
c) pressure and other forces in a fluid are **BALANCED** and there is **NO FLUID MOTION** (at least in the reference frame of the fluid center of mass).
d) the temperature is a constant throughout a fluid.
e) the temperature is not a constant throughout a fluid.
45. Main sequence stars of low mass are mainly supported against collapse ($\gtrsim 90$
a) the pressure of liquid water. b) the ideal gas pressure of ions and electrons. c) the gravitational force. d) angular momentum. e) the solar wind.
46. An everyday example of heat transfer by radiative transport (or radiative transfer) is

- a) boiling water in a pan. b) a spoon in boiling water growing warm. c) sunlight warming.
d) a refrigerator cooling. e) a dog barking.
47. In convection (with downward being the direction of gravity):
- a) hot blobs rise and cold blobs rise too. b) hot blobs rise and cold blobs sink. c) hot and cold blobs both sink.
d) hot and cold blobs don't form. e) hot and cold blobs madly try to consume the universe.
48. A common reason why some astrophysical systems are described as poorly understood is that these systems involve three-dimensional hydrodynamic effects (e.g., convection).
- a) Three-dimensional hydrodynamics cannot be **ACCURATELY COMPUTATIONALLY TREATED** at all.
b) Three-dimensional hydrodynamics cannot be **TREATED EVEN QUALITATIVELY**.
c) Three-dimensional hydrodynamics can **ALWAYS** be understood qualitatively and this allows us to **ALWAYS** predict three-dimensional hydrodynamical phenomena, just not their magnitude. Accurate computations of three-dimensional hydrodynamic effects, however, are only possible in some cases. For example, when **electromagnetic effects** are present, they actually simplify three-dimensional hydrodynamic effects and allow accurate computations in all cases.
d) Three-dimensional hydrodynamics can **OFTEN** be understood qualitatively and this **SOMETIMES** allows us to predict three-dimensional hydrodynamical phenomena. Accurate computations of three-dimensional hydrodynamic effects are also possible in some cases.
e) Three-dimensional hydrodynamics can **OFTEN** be understood qualitatively and this **SOMETIMES** allows us to predict three-dimensional hydrodynamical phenomena. Accurate computations of three-dimensional hydrodynamic effects are also possible in some cases. For example, when **ELECTROMAGNETIC EFFECTS** are present, they actually simplify three-dimensional hydrodynamic effects and allow accurate computations in all cases. Maybe someday all three-dimensional hydrodynamic effects will be accurately calculable.
49. During a star's **MAIN SEQUENCE LIFE**, the star is relatively unchanging. But, of course, it is actually changing slowly on the road to its demise. The key change is that:
- a) carbon dioxide (CO₂) is being expelled by the star's wind.
b) molecular nitrogen (N₂) is being expelled by the star's wind.
c) hydrogen fuel is being exhausted in its core.
d) hydrogen fuel is being exhausted on its surface.
e) helium fuel is being exhausted in its core.
50. Most nuclear-burning stars are main sequence stars. The reason for this is that the main sequence phase of the nuclear-burning life of star of any mass is the:
- a) shortest phase. b) most popular phase. c) wettest phase. d) longest phase.
e) darrest phase.
51. At the time the Sun first became a main sequence star, its luminosity was probably _____ than at present.
- a) 30 % greater b) 100 % greater c) 50 times greater d) 30 % lower e) 100 % lower