## Introductory Astronomy

**Homework 22: The Main Sequence Life of Stars** Not to be handed in. Homework solutions are posted already.

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041 qmult 00100 1 1 1 easy memory: observationally on MS

1. A star lying on the main sequence on a Hertzsprung-Russell diagram is a:

   a) main sequence star. b) pre-main-sequence star. c) post-main-sequence star. d) white dwarf. e) red giant.

   **SUGGESTED ANSWER:** (a)

   **Wrong answers:**

   b) As Lurch would say: "Aaaarh."

   **Redaction:** Jeffery, 2001jan01

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041 qmult 00120 1 4 4 easy-deducto memory: MS energy balance

**Extra keywords:** Sun-question

2. 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.

   **SUGGESTED ANSWER:** (d)

   **Wrong answers:**

   a) Energy from collapse is important during star formation and post-main sequence evolution, but it is not so important on the main sequence itself.

   e) As Lurch would say: "Aaaarh."

   **Redaction:** Jeffery, 2001jan01

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041 qmult 00200 1 1 1 easy memory: nuclei made of protons, neutrons

**Extra keywords:** Sun-question

3. 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.

   **SUGGESTED ANSWER:** (a)

   **Wrong answers:**

   c) A positron is the antiparticle of an electron: i.e., its the antielectron.

   e) As Lurch would say: "Aaaarh."

   **Redaction:** Jeffery, 2001jan01

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041 qmult 00210 1 1 2 easy memory: nucleus small and massive

**Extra keywords:** Sun-question

4. The nucleus is occupies ____________ of the volume of an atom and has ____________ of the atomic mass.

   a) a small part; none b) a small part; almost all c) most; almost all d) most; none e) most; half

   **SUGGESTED ANSWER:** (b)

   **Wrong answers:**
   e) As Lurch would say: "Aaaarh."

   **Redaction:** Jeffery, 2001jan01

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041 qmult 00230 1 4 4 easy deducto-memory: deuteron and triton
**Extra keywords:** Sun-question

5. "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 ($^{235}_{92}$U) and uranium-238 ($^{238}_{92}$U) b) helium-3 ($^{3}_{2}$He) and helium-4 ($^{4}_{2}$He) c) the deuteronomy (D or $^{2}_{1}$H) and trident (T or $^{3}_{1}$H) d) the deuteron (D or $^{2}_{1}$H) and triton (T or $^{3}_{1}$H) e) carbon ($^{12}_{6}$C) and oxygen ($^{16}_{8}$O)

   **SUGGESTED ANSWER:** (d)

   **Wrong answers:**
   b) Helium-3 to helium-4 ratio is about $1/10^6$ by number??? (En-528).
   c) Deuteronomy is the 5th book of the Pentateuch and is a second statement of the Mosaic law. It's about where most would-be-whole Bible readers languish.

   **Redaction:** Jeffery, 2001jan01

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041 qmult 00240 1 1 2 easy memory: strong nuclear force binds nuclei
**Extra keywords:** Sun-question

6. Nuclei are bound together by:

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

   **SUGGESTED ANSWER:** (b)

   **Wrong answers:**
   d) As Lurch would say: "Aaaarh." This not a real force, but rather the tendency of objects in a rotating frame to try to go in a straight line.

   **Redaction:** Jeffery, 2001jan01

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041 qmult 00250 1 1 2 easy memory: nuclear fusion defined
**Extra keywords:** CK-261,266 Sun-question

7. 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

   **SUGGESTED ANSWER:** (b)

**Wrong answers:**
e) This is fission, not fusion.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00260 2 1 3 moderate memory: 4 hydrogen nuclei to 1 helium
**Extra keywords:** CK-262,267 Sun-question

8. In hydrogen burning how many hydrogen nuclei are **CONSUMED** in producing one helium-4 nucleus (i.e., one ${}^4_2$He nucleus)?

   a) 1. b) 2. c) 4. d) 10. e) 6.5.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
e) Half a proton?

**Redaction:** Jeffery, 2001jan01

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041 qmult 00280 1 3 2 easy math: E=mc**2 calculation 1 kg
**Extra keywords:** Sun-question

9. 1 kg of matter is equivalent to about how much energy? Recall that the speed of light is $3.00 \times 10^8$ m/s.

   a) $8 \times 10^{16}$ J. b) $9 \times 10^{16}$ J. c) $9 \times 10^8$ J. d) $3 \times 10^8$ J. e) $2 \times 10^8$ J.

**SUGGESTED ANSWER:** (b) Everyone must remember $E = mc^2$. We note that 1 megaton TNT yields $4.16 \times 10^{15}$ J explosion energy (WP-A-20) which I suppose counts both heat and macroscopic kinetic energy. Thus, if one could transform 1 kg of matter into explosive energy one would have a 20 megaton bomb. Fortunately, this reaction though energetically allowed is forbidden by other rules. We would, of course, like to change rest mass energy into useful energy in a controlled manner: i.e., controlled fusion.

**Wrong answers:**
d) You forgot to square the $c$.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00300 1 1 2 easy memory: MS hydrogen burning I
**Extra keywords:** Sun-question

10. 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.

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
a) Wrong way around.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00310 1 1 5 easy memory: MS hydrogen burning II
**Extra keywords:** CK-310 Sun-question

11. Main sequence stars burn (in the nuclear sense):

a) helium to carbon in their cores. b) helium to carbon on their surfaces. c) helium to hydrogen on their surfaces. d) helium to hydrogen in their cores. e) hydrogen to helium in their cores.

**SUGGESTED ANSWER:** (e)

**Wrong answers:**
b) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 00320 1 1 2 easy memory: thermonuclear reactions in star cores
**Extra keywords:** CK-267-12 Sun-question

12. 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

**SUGGESTED ANSWER:** (b) See CK-263 and Cox-342.

**Wrong answers:**
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 00330 1 1 1 easy memory: nuclear burning on star surface I
**Extra keywords:** CK-322-4 Sun-question

13. 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.

**SUGGESTED ANSWER:** (a)

**Wrong answers:**
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 00400 1 5 2 easy thinking: detailed star modeling 1
**Extra keywords:** Sun-question

14. 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.

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
c) It would be nice if one could do such experiments but they are not needed and one would still have to do modeling anyway.
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 00420 1 4 3 easy deducto-memory: star model described

**Extra keywords:** CK-267-11 Sun-question

15. "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

**SUGGESTED ANSWER:** (c)

**Wrong answers:**

e) C'mon.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00430 1 4 1 easy deducto-memory: radial variation in a star

**Extra keywords:** Sun-question

16. In a main sequence star (e.g., the Sun) temperature, density, and pressure:

a) vary strongly from center to surface (i.e., photosphere).
b) are constant throughout the star.
c) are never higher than about $6000\,\mathrm{K}$, $2 \times 10^{-7}\,\mathrm{g/cm^3}$, and 0.8 Earth atmospheres, respectively.
d) are all equal to 6000 in MKS units.
e) are completely unknown.

**SUGGESTED ANSWER:** (a) This should be pretty easy.

**Wrong answers:**

c) These are approximately the Sun surface values according to Cox-342, where surface means photosphere.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00500 1 4 3 easy deducto-memory: hydrostatic equilibrium

**Extra keywords:** Sun-question

17. 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.

**SUGGESTED ANSWER:** (c) The answer should be determinable from the expression itself.

**Wrong answers:**

a) "Unbalanced" is not right for an expression containing the word "equilibrium."

**Redaction:** Jeffery, 2001jan01

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041 qmult 00510 1 4 5 easy deducto-memory: everyday hydrostatic
**Extra keywords:** CK-267-9 Sun-question

18. "Let's play *Jeopardy*! For $100, the answer is: It is an everyday example of hydrostatic equilibrium."

What is ____________, Alex?

a) a boat's wake b) stirring coffee c) a river d) a waterfall e) water at rest in a cup

**SUGGESTED ANSWER:** (e)

**Wrong answers:**
a) It's sloshing around.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00520 1 1 2 easy memory: star pressure support
**Extra keywords:** CK-261, Sun-question

19. Main sequence stars of low mass are mainly supported against collapse ( $\gtrsim 90\,\%$ for $M \lesssim 8M_\odot$) by:

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.

**SUGGESTED ANSWER:** (b) I vaguely thought that radiation pressure was important in the Sun. But no, Cl-163–165 shows that radiation pressure is close to negligible in low-mass main sequence stars.

**Wrong answers:**
c) Gravity is the force trying to cause collapse.
d) angular momentum gives a bit of support and helps to make the Sun bulge at the equator a bit, I suppose.

**Redaction:** Jeffery, 2001jan01

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041 qmult 00610 1 5 3 easy thinking: radiative transfer everyday
**Extra keywords:** CK-267-10, Sun-question

20. 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.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 00730 2 1 4 moderate memory: 3-d hydrodynamic effects
**Extra keywords:** Sun-question

21. 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 hydrodyamics cannot be **ACCURATELY COMPUTATIONALLY TREATED** at all.
b) Three-dimensional hydrodyamics cannot be **TREATED EVEN QUALITATIVELY**.

c) Three-dimensional hydrodyamics 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 hydrodyamics 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 hydrodyamics 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.

**SUGGESTED ANSWER:** (d)

**Wrong answers:**
a) Nope. They can be treated computationally sometimes: sometimes accurately, often less so.
b) Qualitative understanding is often possible, at least by analogy to experimentally studied systems or simplified computational models.
c) No they can't always be understood qualitatively: at least not in the sense of being able to predict what will happen. More often what happens is qualitatively understandable in the sense that we can see how it could be so, but without have seen it, wouldn't have been able to predict that it would be so. Of course, sometimes, a phenomena is totally mysterious.
e) This is all right, except that electromagnetic effects usually complicate not simplify a 3-d problem.

**Redaction:** Jeffery, 2001jan01

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041 qmult 01000 2 4 3 moderate deducto-memory: main sequence evolution
**Extra keywords:** Sun-question, Sunlife

22. 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 ($CO_2$) is being expelled by the star's wind.
b) molecular nitrogen ($N_2$) 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.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
e) Helium fuel is burnt during some post-main-sequence phases.

**Redaction:** Jeffery, 2001jan01

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041 qmult 01010 1 1 4 easy memory: main sequence longest phase
**Extra keywords:** CK-322-6, Sun-question, Sunlife

23. 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) darnest phase.

**SUGGESTED ANSWER:** (d) See CK-311

**Wrong answers:**
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 01030 2 4 4 mod. deducto-memory: early Sun luminosity
**Extra keywords:** Sun-question, Sunlife

24. 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

**SUGGESTED ANSWER:** (d)

**Wrong answers:**
e) Now this doesn't seem very likely does it.

**Redaction:** Jeffery, 2001jan01

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041 qmult 01100 1 4 2 easy deducto-memory: red dwarfs
**Extra keywords:** CK-311,321,322-10

25. These main sequence stars have masses in the range 0.08–0.4 $M_\odot$. They have the lowest temperatures and densities in their cores of all main sequence stars and subsequently burn hydrogen to helium most slowly. Convection occurs throughout these stars and eventually they will be converted entirely into helium. They will never burn any other nuclear fuel and eventually must become helium white dwarfs. Their main sequence lifetimes are predicted by models to be hundreds of billions of years. According to our current cosmological theory the age of the universe is only about 14 billion years. Thus, none of these stars has ever left the main sequence. These stars are called:

a) brown dwarfs. b) red dwarfs. c) white dwarfs. d) red giants. e) O stars.

**SUGGESTED ANSWER:** (b) See CK-311

**Wrong answers:**
e) O stars are the most massive main sequence stars with masses up to about 100 $M_\odot$ (CK-305).

**Redaction:** Jeffery, 2001jan01

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041 qmult 01120 1 4 3 easy deducto-memory: red dwarfs go helium
**Extra keywords:** CK-311,321,322-10

26. Because red dwarf stars are convective throughout (i.e., from center to photosphere), they will

a) burn helium to hydrogen only in their cores. b) never burn hydrogen at all. c) eventually burn almost all their hydrogen to helium. d) never burn either hydrogen or helium. e) burn carbon before hydrogen.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 01200 1 4 2 easy deducto-memory: brown dwarf defined
**Extra keywords:** CK-306,321

27. An object that forms in a star formation region with less than about $0.08\,M_\odot$, but more than about 13 Jupiter masses (according to one school of thought), and which never burns ordinary hydrogen is called a:

a) white dwarf. b) brown dwarf. c) red dwarf. d) red giant. e) green giant.

**SUGGESTED ANSWER:** (b)

**Wrong answers:**
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01

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041 qmult 01210 1 1 1 easy memory: brown dwarfs are not MS stars
**Extra keywords:** CK-306,321

28. Brown dwarfs are:

a) not main sequence stars ever. b) unarguably main sequence stars. c) main sequence stars at three different times. d) sometimes main sequence stars. e) the same things as red giants.

**SUGGESTED ANSWER:** (a)

**Wrong answers:**
b) Well they burn deuterons in their cores briefly and deuteron is heavy hydrogen and main sequence stars are stars that burn ordinary hydrogen in their cores, but I'm prepared to argue that brown dwarfs are not main sequence stars ever, and so this answer can't be right.
e) As Lurch would say: "Aaaarh."

**Redaction:** Jeffery, 2001jan01