

Introductory Astronomy**NAME:**

Homework 22: The Main Sequence Life of Stars: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems (~ 50–70%) will turn up on tests.

Answer Table

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001 qmult 00007 1 4 1 easy deducto-memory: reading done 2

1. Did you complete reading the intro astro web lecture before the **SECOND DAY** on which the lecture was lectured on in class?

a) YYYessss! b) Jawohl! c) Da! d) Sí, sí. e) OMG no!

SUGGESTED ANSWER: (a),(b),(c),(d)

Wrong answers:

e) As Lurch would say AAAARGH.

Redaction: Jeffery, 2008jan01

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

2. 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

041 qmult 00110 1 4 5 easy deducto-memory: main sequence star physically

Extra keywords: CK-310 Sun-question

3. “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

SUGGESTED ANSWER: (e)

Wrong answers:

d) Oh, c’mon.

Redaction: Jeffery, 2001jan01

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

Extra keywords: Sun-question

4. 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

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

Extra keywords: Sun-question

5. 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

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

Extra keywords: Sun-question

6. The nucleus 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

041 qmult 00220 1 1 3 easy memory: isotopes defined

Extra keywords: Sun-question

7. 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

SUGGESTED ANSWER: (c)

Wrong answers:

- a) Contours of the same time.
 b) Contours of the same pressure.
 d) Contours of the same stupidity.
 e) Isolde or Iseult is the heroine (heroin?) of the Arthurian romance of Tristan and Isolde:

Nay, order him!
 Pray understand it!
 I command it.
 I Isolde.

Redaction: Jeffery, 2001jan01

041 qmult 00230 1 4 4 easy deducto-memory: deuteron and triton

Extra keywords: Sun-question

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

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

041 qmult 00240 1 1 2 easy memory: strong nuclear force binds nuclei

Extra keywords: Sun-question

9. 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

041 qmult 00250 1 1 2 easy memory: nuclear fusion defined

Extra keywords: CK-261,266 Sun-question

10. 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

041 qmult 00270 2 4 3 moderate deducto-memory: H fusion mass loss

Extra keywords: Sun-question

11. 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 mostly 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

SUGGESTED ANSWER: (c)

Wrong answers:

- e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001jan01

041 qmult 00280 1 3 2 easy math: $E=mc^2$ calculation 1 kg

Extra keywords: Sun-question

12. 1 kg of matter is equivalent to about 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.

SUGGESTED ANSWER: (b)

Everyone must remember $E = mc^2$. We note that 1 megaton TNT yields 4.16×10^{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

041 qmult 00300 1 1 2 easy memory: MS hydrogen burning 1

Extra keywords: Sun-question

13. 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

041 qmult 00320 1 1 2 easy memory: thermonuclear reactions in star cores

Extra keywords: CK-267-12 Sun-question

14. 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

041 qmult 00330 1 1 1 easy memory: nuclear burning on star surface 1

Extra keywords: CK-322-4 Sun-question

15. 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

041 qmult 00400 1 5 2 easy thinking: detailed star modeling 1

Extra keywords: Sun-question

16. 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

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

Extra keywords: CK-267-11 Sun-question

17. "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

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

Extra keywords: Sun-question

18. 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 K, 2×10^{-7} g/cm³, 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

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

Extra keywords: Sun-question

19. 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

041 qmult 00510 1 4 5 easy deducto-memory: everyday hydrostatic

Extra keywords: CK-267-9 Sun-question

20. "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

041 qmult 00520 1 1 2 easy memory: star pressure support

Extra keywords: CK-261, Sun-question

21. 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

041 qmult 00610 1 5 3 easy thinking: radiative transfer everyday

Extra keywords: CK-267-10, Sun-question

22. 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

041 qmult 00710 1 4 2 easy deducto-memory: convection described

Extra keywords: CK-267-10, Sun-question

23. In convection between a lower hot layer and an upper cold layer (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.

SUGGESTED ANSWER: (b) This is energy transfer by EMR.

Wrong answers:

- e) We all remember that classic Steve MacQueen flick *The Blob*.

Redaction: Jeffery, 2001jan01

041 qmult 00730 2 1 4 moderate memory: 3-d hydrodynamic effects

Extra keywords: Sun-question

24. 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.

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

041 qmult 01000 2 4 3 moderate deducto-memory: main sequence evolution

Extra keywords: Sun-question, Sunlife

25. 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.

SUGGESTED ANSWER: (c)

Wrong answers:

- e) Helium fuel is burnt during some post-main-sequence phases.

Redaction: Jeffery, 2001jan01

041 qmult 01010 1 1 4 easy memory: main sequence longest phase

Extra keywords: CK-322-6, Sun-question, Sunlife

26. 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) darndest phase.

SUGGESTED ANSWER: (d) See CK-311

Wrong answers:

- e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

041 qmult 01020 2 4 2 moderate deducto-memory: main sequence brightening

Extra keywords: Sun-question, Sunlife

27. As a **MAIN SEQUENCE STAR** ages, its luminosity (i.e., total energy output):

- a) decreases.
- b) increases.
- c) oscillates wildly.
- d) becomes tangential.
- e) incinerates.

SUGGESTED ANSWER: (b) See Se-246.

Wrong answers:

- a) As the fuel is being exhausted this seems reasonable. But in fact the fuel burns more rapidly as it is expended.
- d) A nonsense answer.

- e) Luminosity is a characteristic of a substance, not a substance itself: the verb incinerate cannot apply to luminosity.

Redaction: Jeffery, 2001jan01

041 qmult 01030 2 4 4 mod. deducto-memory: early Sun luminosity

Extra keywords: Sun-question, Sunlife

28. 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

041 qmult 01100 1 4 2 easy deducto-memory: red dwarfs

Extra keywords: CK-311,321,322-10

29. These main sequence stars have masses in the range $0.08\text{--}0.4 M_{\odot}$. 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

041 qmult 01110 1 4 3 easy deducto-memory: convective red dwarfs

Extra keywords: CK-311,321,322-10

30. Red dwarf stars are convective:
- a) in no region. b) only above the photosphere. c) from center to photosphere. d) only in the nuclear burning core. e) occasionally.

SUGGESTED ANSWER: (c)

Wrong answers:

- e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

041 qmult 01120 1 4 3 easy deducto-memory: red dwarfs go helium

Extra keywords: CK-311,321,322-10

31. 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

041 qmult 01200 1 4 2 easy deducto-memory: brown dwarf defined

Extra keywords: CK-306,321

32. 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

041 qmult 01210 1 1 1 easy memory: brown dwarfs are not MS stars

Extra keywords: CK-306,321

33. 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 deuterium 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