Introductory Astronomy **NAME:**

Homework 9: The Life of the Sun: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems ($\sim$ 50–70 %) will turn up on tests.

Answer Table

Name:

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	37.	O	O	O	O	O
2.	O	O	O	O	O	38.	O	O	O	O	O
3.	O	O	O	O	O	39.	O	O	O	O	O
4.	O	O	O	O	O	40.	O	O	O	O	O
5.	O	O	O	O	O	41.	O	O	O	O	O
6.	O	O	O	O	O	42.	O	O	O	O	O
7.	O	O	O	O	O	43.	O	O	O	O	O
8.	O	O	O	O	O	44.	O	O	O	O	O
9.	O	O	O	O	O	45.	O	O	O	O	O
10.	O	O	O	O	O	46.	O	O	O	O	O
11.	O	O	O	O	O	47.	O	O	O	O	O
12.	O	O	O	O	O	48.	O	O	O	O	O
13.	O	O	O	O	O	49.	O	O	O	O	O
14.	O	O	O	O	O	50.	O	O	O	O	O
15.	O	O	O	O	O	51.	O	O	O	O	O
16.	O	O	O	O	O	52.	O	O	O	O	O
17.	O	O	O	O	O	53.	O	O	O	O	O
18.	O	O	O	O	O	54.	O	O	O	O	O
19.	O	O	O	O	O	55.	O	O	O	O	O
20.	O	O	O	O	O	56.	O	O	O	O	O
21.	O	O	O	O	O	57.	O	O	O	O	O
22.	O	O	O	O	O	58.	O	O	O	O	O
23.	O	O	O	O	O	59.	O	O	O	O	O
24.	O	O	O	O	O	60.	O	O	O	O	O
25.	O	O	O	O	O	61.	O	O	O	O	O
26.	O	O	O	O	O	62.	O	O	O	O	O
27.	O	O	O	O	O	63.	O	O	O	O	O
28.	O	O	O	O	O	64.	O	O	O	O	O
29.	O	O	O	O	O	65.	O	O	O	O	O
30.	O	O	O	O	O	66.	O	O	O	O	O
31.	O	O	O	O	O	67.	O	O	O	O	O
32.	O	O	O	O	O	68.	O	O	O	O	O
33.	O	O	O	O	O	69.	O	O	O	O	O
34.	O	O	O	O	O	70.	O	O	O	O	O
35.	O	O	O	O	O	71.	O	O	O	O	O
36.	O	O	O	O	O	72.	O	O	O	O	O

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

1. Did you complete reading the Introductory Astronomy 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

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040 qmult 00100 1 4 3 easy deducto-memory: life history of Sun
Extra keywords: Sunlife

2. The life history of our own star, the Sun, is known to us by:

   a) direct observations of all of its stages.
   b) direct observations of most of its stages plus observations of other stars in all their stages and modeling.
   c) direct observations of its current stage plus observations of other stars in all their stages and modeling.
   d) modeling alone.
   e) sheer guesswork.

   SUGGESTED ANSWER: (c)

   We only directly observe the Sun in its current stage: i.e., the middle main sequence stage. The Sun has been there all of human history and will be there all of foreseeable human history.

   Wrong answers:
   e) "Sheer" and "guesswork" are correctly spelt anyway.

   Redaction: Jeffery, 2001jan01

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040 qmult 00200 1 1 5 easy memory: interstellar medium (ISM) defined 1
Extra keywords: CK-299,321, Sunlife

3. The interstellar medium (ISM) consists of:

   a) planets. b) molecular clouds only. c) stars. d) dust only. e) gas and dust.

   SUGGESTED ANSWER: (e)

   Wrong answers:
   a) As Lurch would say: "Aaaarh."

   Redaction: Jeffery, 2001jan01

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040 qmult 00310 1 4 1 easy deducto-memory: nebula defined
Extra keywords: CK-302,321, Sunlife

4. In modern astronomy, a nebula (plural nebulae) is a:

   a) cloud of a gas in space. b) large main sequence star. c) small main sequence star. d) bright star. e) young star.

   SUGGESTED ANSWER: (a)

   There are many kinds of nebulae: e.g., emission, dark, supernova remnant, reflection, and spiral nebulae: the last one is just a historical name since the spiral nebulae are spiral galaxies and not clouds, but before they were known to be galaxies were called nebulae because they looked like clouds to telescopic observers.

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

   Redaction: Jeffery, 2001jan01

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040 qmult 00320 1 1 5 easy memory: molecular cloud and stars
Extra keywords: CK-321, Sunlife

5. The dense, cold component of the interstellar medium from which stars are believed to form is made of:

   a) H II (ionized hydrogen) regions. b) white dwarfs. c) protostars. d) Lyman-Alpha forests. e) molecular clouds.

   SUGGESTED ANSWER: (e) See Se-220. The molecular clouds don't always have to be giant molecular clouds: are they usually giant molecular clouds?

   Wrong answers:

   d) Some of these critters probably do end up helping to make stars.

   Redaction: Jeffery, 2001jan01

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040 qmult 00330 2 1 5 moderate memory: molecular cloud composition
Extra keywords: CK-300, Sunlife

6. The composition of molecular clouds in the interstellar medium is dominated by:

   a) carbon dioxide. b) molecular oxygen only. c) helium gas only. d) amino acids. e) molecular hydrogen gas and helium gas.

   SUGGESTED ANSWER: (e)

   Hydrogen and helium dominate the composition of the universe and a molecular cloud should have molecules. Zeilik p. 332 confirms that the hydrogen in molecular clouds is molecular hydrogen.

   Wrong answers:

   a) Carbon dioxide is an important tracer of molecular clouds, but it is a minority species.

   Redaction: Jeffery, 2001jan01

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040 qmult 00410 3 4 1 tough deducto-memory: molecular clouds and their dust
Extra keywords: Sunlife , long question

7. Molecular clouds are probably about 1 per cent dust by mass.

   a) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
   b) The dust is **VERY IMPORTANT** to these clouds. It is **COMPLETELY TRANSPARENT** to visible and ultraviolet light, and allows plenty of hard electromagnetic radiation into the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
   c) The dust is **COMPLETELY UNIMPORTANT** to these clouds. True, the dust is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.
   d) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of

molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.

e) The presence of this dust is just coincidental. It just happens that where there is dust there are molecular clouds, and where there is no dust there arn't. Things could be entirely otherwise; they just arn't.

SUGGESTED ANSWER: (a) The problem discusses details that weren't and needn't be emphasized in class. But it shows who's thinking. See Se-212 and Zeilik p. 333, 337.

Wrong answers:

b) Hard radiation tends to break up molecules, whose bonds are not that robust. Thus the premise and conclusion of the answer disagree.

c) No, dust is important and molecular clouds and dust usually go together. But there can be dust without molecules and the reverse is probably true. But giant molecular clouds probably always have a lot of dust.

d) No, there arn't molecular clouds where one can see the star formation process in the visible: it seems to be always dust-shrouded.

e) Coincidences due happen, but modern science always suspects (and sometimes wrongly) that behind any seeming coincidence lies a a relationship.

Redaction: Jeffery, 2001jan01

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040 qmult 00420 2 4 3 moderate deducto-memory: molecular cloud dust described

Extra keywords: Sunlife

8. Interstellar dust probably varies widely in composition, size scale, and structure. But there some ideas about typical dust that are generally accepted.

a) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **VOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **NONVOLATILES** condense out on the cores.

b) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

c) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **NONVOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **VOLATILES** condense out on the cores.

d) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\text{m} = 10^{-6}\,\text{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\text{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.

e) The dust is found under sofas and on other untouched surfaces. It gets there by settling out the air. One often sees dust in air the reflecting bright sunlight.

SUGGESTED ANSWER: (c) See Zeilik p. 336–337.

Wrong answers:

a) Volatile and nonvolatile mix-up.

b) Volatile and nonvolatile mix-up. If it forms in a black hole, it doesn't get out. By the by, a scot is an archaic term for a payment or a tax derived from Scandinavian languages: it has nothing to do with laddies and lassies in kilts.

d) If it forms in a black hole, it doesn't get out.

e) This is terrestrial dust. I wonder what terrestrial dust is made of. Probably pretty various although some has to be silicates.

Redaction: Jeffery, 2001jan01

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040 qmult 00510 1 4 5 easy deducto-memory: movement on HR diagram

Extra keywords: CK-322-12

9. "Let's play *Jeopardy*! For \$100, the answer is: It happens whenever a star changes its luminosity and/or its surface temperature."

What is ____________, Alex?

a) explodes b) collapses c) turns green d) becomes a white dwarf e) movement on the Hertzsprung-Russell (HR) diagram

SUGGESTED ANSWER: (e)

Wrong answers:

a) This would change luminosity and surface temperature, but it does not happen "whenever."

Redaction: Jeffery, 2001jan01

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040 qmult 00610 2 4 1 moderate deducto-memory: star formation triggers

Extra keywords: CK-302, Sunlife

10. Star formation in a dusty molecular cloud probably requires some triggering event to initiate the collapse to dense cores that will become stars. Two possible trigger mechanisms are:

a) **SUPERNOVAE** which compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.

b) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.

c) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **PROTOSTAR-PROTOSTAR COLLISIONS** which also compress the molecular clouds.

d) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.

e) **WHITE HOBBITS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.

SUGGESTED ANSWER: (a)

Wrong answers:

b) White dwarfs are miniscule compared to molecular clouds and would just run through them like beads of sand.

c) This is probably a pretty rare event and wouldn't compress clouds much.

e) Yes Tolkien has invaded space, but there are no white hobbits as far as I know.

Redaction: Jeffery, 2001jan01

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040 qmult 00710 2 4 2 moderate deducto-memory: free-fall molecular cloud

Extra keywords: Sunlife

11. In a **FREE-FALL** contraction of part of molecular cloud:

a) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces slow the fall from the beginning.
b) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces are negligible in slowing the fall because it is a free-fall contraction.
c) the entire molecular cloud collapses to form a black hole.
d) the part collapses to form a black hole.
e) planetesimals collide and break apart.

SUGGESTED ANSWER: (b)

Wrong answers:
e) The planetesimals are a much later stage in Solar System formation.

Redaction: Jeffery, 2001jan01

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040 qmult 00720 1 4 1 easy deducto-memory: dense core defined sort of
Extra keywords: CK-303,321, Sunlife
12. The collapsing dense regions that develop into stars and initially have temperatures of order 10 K are called:

a) dense cores. b) dilute cores. c) main sequence stars. d) white dwarfs.
e) rotten cores.

SUGGESTED ANSWER: (a)

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

Redaction: Jeffery, 2001jan01

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040 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife
13. A protostar is sometimes conveniently defined to be a:

a) star that can no longer burn hydrogen to produce heat energy.
b) white dwarf.
c) dense core of gas contracting to become a star that is hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
d) molecular cloud that will become a star.
e) giant molecular cloud that will become a star.

SUGGESTED ANSWER: (c) Se-222, gives this definition and FK-450 implicitly agrees. He calls the protostar a prestellar object, but that seems too convoluted for me. But the term is used loosely in astronomy I think.

Wrong answers:
e) A white dwarf is at the far end of stellar evolution.

Redaction: Jeffery, 2001jan01

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040 qmult 00810 2 4 5 moderate deducto-memory: protostar contraction 1
Extra keywords: FK-451 agree with this, Sunlife
14. The contraction of a protostar is halted eventually by:

a) the thermal energy generated by the contraction which **DECREASES** the gas pressure inside the protostar.
b) the thermal energy generated by the contraction which **INCREASES** the gas pressure inside the protostar.
c) the action of magnetic fields.
d) the action of the dynamo effect.
e) the heat generated by the turning on of nuclear burning which **INCREASES** the gas pressure inside the protostar.

SUGGESTED ANSWER: (e)

Wrong answers:
a) Adding heat and contraction together should increase gas pressure.
b) The thermal energy generated by contraction and the increasing density of the gas do increase pressure, but they do not stop the contraction.

Redaction: Jeffery, 2001jan01

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040 qmult 01000 1 4 1 easy deducto memory: H II region defined
Extra keywords: CK-307,321,322-3

15. Star formation in giant molecular clouds often results in the formation of OB associations: collections of hot, bright OB stars that ionize the surrounding molecular cloud and evaporate dust because of their strong ultraviolet emission. The gas region ionized by an OB associations is called a/an:

a) H II region. b) small molecular cloud. c) black hole. d) dark cloud.
e) He region.

SUGGESTED ANSWER: (a)

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

Redaction: Jeffery, 2001jan01

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040 qmult 01500 1 4 3 easy deducto-memory: disk defined
Extra keywords: Sunlife

16. "Let's play *Jeopardy*! For \$100, the answer is: They are relatively thin, round objects consisting of gas and/or dust and/or particles: the material goes around some large astro-body in nearly circular orbits of varying radii in the same direction."

What are ____________, Alex?

a) CDs b) planets c) disks d) satellites e) projectiles

SUGGESTED ANSWER: (c)

Wrong answers:
a) Compact disks are disks, but not the right kind of disk.

Redaction: Jeffery, 2001jan01

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040 qmult 01510 2 4 2 moderate deducto-memory: disk formation frequency
Extra keywords: CK-304, Sunlife

17. Disk formation is:

a) a unique event that happened only in the case of the formation of the Sun.
b) a common event in star formation as far as astronomers can tell.
c) a process in nuclear burning.
d) never observed in star formation.
e) responsible for the heating up of the protostar.

SUGGESTED ANSWER: (b)

Wrong answers:
d) It has been observed.

Redaction: Jeffery, 2001jan01

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040 qmult 01512 3 5 3 hard thinking: disk formation 1
Extra keywords: defective problem. Must get the story straight. Sunlife

18. Disk formation is believed to happen fairly generally:

a) in star formation, in the formation of accretion disks about putative black holes, and in the **FORMATION OF SPIRAL GALAXIES**. In the case of black holes, matter is **SPRAYED OUT** of the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk.

b) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF SPIRAL GALAXIES**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **COOLS DOWN**.

c) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF SPIRAL GALAXIES**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **HEATS UP** due to infall kinetic energy being transformed into heat. Consequently, the infalling material radiates electromagnetic radiation. The object Sgr A* near or at the dynamical center of the Milky Way, thought to be a black hole of mass of order $3 \times 10^6\, M_\odot$, is a strong radio source.

d) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF IMPACT CRATERS**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **COOLS DOWN**.

e) in star formation, in the formation of accretion disks about black holes, and in the **FORMATION OF IMPACT CRATERS** In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **GRAVITATIONALLY CAPTURED** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **HEATS UP** due to infall kinetic energy being transformed into heat. Consequently, the infalling material radiates electromagnetic radiation. The object Sgr A* near or at the dynamical center of the Milky Way, thought to be a black hole of mass of order $3 \times 10^6\, M_\odot$, is a strong radio source.

SUGGESTED ANSWER: (c)

Wrong answers:

a) Everyone knows that no matter escapes a black hole: at least not in a direct classical sense.
b) The infalling matter should heat up.
d) Not impact craters.
e) Not impact craters.

Redaction: Jeffery, 2001jan01

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041 qmult 00110 1 4 5 easy deducto-memory: main sequence star physically
Extra keywords: CK-310 Sun-question

19. “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

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041 qmult 00120 1 4 4 easy-deducto memory: MS energy balance
Extra keywords: Sun-question

20. 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

21. 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

22. 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 00220 1 1 3 easy memory: isotopes defined
Extra keywords: Sun-question

23. 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

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

24. "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 fraction of terrestrial helium is 1.37×10^{-6} by number??? (see Wikipedia: Helium-3).
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

25. 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

26. 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 00270 2 4 3 moderate deducto-memory: H fusion mass loss
Extra keywords: Sun-question

27. 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

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

28. A mass of 1 kg 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

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

29. 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 00320 1 1 2 easy memory: thermonuclear reactions in star cores
Extra keywords: CK-267-12 Sun-question

30. 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 1
Extra keywords: CK-322-4 Sun-question

31. 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

32. 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

33. "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

34. 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 $6000\,\mathrm{K}$, $2\times10^{-7}\,\mathrm{g/cm^3}$, 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

35. 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 the 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

36. "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

37. 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

38. 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 00710 1 4 2 easy deducto-memory: convection described
Extra keywords: CK-267-10, Sun-question

39. 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

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

40. 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

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

41. 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

42. 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

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041 qmult 01020 2 4 2 moderate deducto-memory: main sequence brightening
Extra keywords: Sun-question, Sunlife

43. 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

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

44. 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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042 qmult 00100 2 4 2 moderate deducto-memory: main sequence phase ends 1
Extra keywords: Sun-question

45. The end of a star's **MAIN SEQUENCE LIFE** (not its nuclear burning life) comes when it has:

a) exhausted the hydrogen fuel in its corona. b) exhausted the hydrogen fuel in its core region. c) become a white dwarf. d) become a green dwarf. e) exhausted the hydrogen fuel in its sunspots.

SUGGESTED ANSWER: (b)

Wrong answers:
e) Sunspots on other stars are usually called starspots. I once was a colleague of Doug Hall, a great starspot expert: he's now retired: it seems like a long time ago.

Redaction: Jeffery, 2001jan01

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042 qmult 00102 1 1 1 easy memory: main sequence phase ends 2
Extra keywords: Sun-question

46. When a star exhausts its core hydrogen fuel its:

a) main sequence phase is ended. b) main sequence phase is at midpoint. c) main sequence phase is beginning. d) red giant phase is ended. e) AGB phase is ended.

SUGGESTED ANSWER: (a)

Wrong answers:

c) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001jan01

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042 qmult 00110 2 4 4 moderate deducto-memory: post-main sequence of Sun

Extra keywords: Sun-question

47. After the end of its main sequence lifetime, the Sun will probably go through the following phases in order:

a) red giant, helium flash (a very short stage), horizontal branch star, green giant, cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
b) red giant, helium flash (a very short stage), horizontal branch star, jolly green giant, planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
c) red giant, helium flash (a very short stage), vertical branch star, second red giant (i.e., asymptotic [red] giant branch star or ABG star), cometary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
d) red giant, helium flash (a very short stage), horizontal branch star, second red giant (i.e., asymptotic [red] giant branch star or ABG star), planetary nebula/pre-white dwarf, white dwarf, black dwarf (very far in the future).
e) red giant, Larry, Curly, Moe, black dwarf (very far in the future).

SUGGESTED ANSWER: (d) See Se-250–252 and Sh-152. Note only stars in the 0.4–3 $M_\odot$ range have a helium flash.

Wrong answers:

e) Larry, Curly, Moe—you get it—Larry, Curly, . . .

Redaction: Jeffery, 2001jan01

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042 qmult 00200 1 4 5 easy deducto-memory: red giants defined sort of

Extra keywords: CK-288,296 Sun-question

48. “Let’s play *Jeopardy*! For $100, the answer is: These stars typically have radiii 10 to 100 times that of the Sun and surface temperatures of 2000–4500 K.”

What are ____________, Alex?

a) white dwarfs b) green dwarfs c) red dwarfs d) blue giants e) red giants

SUGGESTED ANSWER: (e)

Wrong answers:

c) Now if they are much bigger than the Sun they wouldn’t be dwarfs would they.

Redaction: Jeffery, 2001jan01

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042 qmult 00210 2 1 2 moderate memory: star to red giant

Extra keywords: Sun-question

49. After its hydrogen-burning life main sequence, a star usually will:

a) expand into a blue supergiant. b) expand into a red giant. c) shrink into a red dwarf.
d) just fade out. e) implode to form a protostar.

SUGGESTED ANSWER: (b)

Wrong answers:

e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001jan01

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042 qmult 00300 2 4 3 moderate deducto-memory: horizontal branch star defined

Extra keywords: CK-327, Sh-149, Sun-question life

50. Lower mass stars (i.e., those which had main sequence mass $\lesssim 8 M_\odot$) when burning helium to carbon and oxygen in their **CORES** are called ____________ stars.

a) red giant b) supergiant c) horizontal branch d) vertical branch e) oblique branch

SUGGESTED ANSWER: (c) Sh-149 limits the term to stars that don't become core-collapse supernovae which seems right to me.

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

Redaction: Jeffery, 2001jan01

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042 qmult 00400 2 4 2 moderate deducto-memory: AGB star defined
Extra keywords: CK-328,346, FK-496,497, Sun-question

51. Lower mass stars (i.e., those which had main sequence mass $\lesssim 4M_\odot$) when burning helium to carbon and oxygen in a shell around an inert carbon-oxygen core, but before they have lost a lot of mass in helium shell flashes, are called ____________ stars.

a) red dwarf b) asymptotic giant branch (AGB) c) horizontal branch d) vertical branch e) oblique branch

SUGGESTED ANSWER: (b) CK and FK disagree a bit about what happens to 4–8$M_\odot$ stars. But certainly what happens below $4M_\odot$ is clear.

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

Redaction: Jeffery, 2001jan01

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042 qmult 00410 1 4 3 easy deducto-memory: AGB Sun vaporizes Earth
Extra keywords: Sun-question

52. If in its AGB (asymptotic red giant) phase (or 2nd red giant phase), the Sun has expanded and enveloped the Earth, the Earth will:

a) very quickly collapse to a black hole.
b) become a red giant star.
c) spiral into the deeper layers of the Sun because of the drag forces of the Sun's outer layers. There the Earth will be totally vaporized. "So the glory of this world passes away": *Sic transit gloria mundi.*
d) gain escape velocity and be ejected from the solar system because of the drag forces of the Sun's outer layers.
e) implode to form a protostar.

SUGGESTED ANSWER: (c) Zeilik p. 359 gives the Earth only about 200 years of survival after envelopment.

I once carried on a conversation in Latin: "E pluribus unum", "tempus fugit", "natura nonsaltum", "O tempores, O mores", "in vino veritas".

Wrong answers:
a) We havn't discussed black holes, but I don't think this answer would seem plausible compared to the others.
b) This is what the Sun is doing, not the Earth.
d) Drag forces slow down, they don't accelerate. They always oppose motion.
e) The Earth is much too small to become a protostar and why would it do this.

Redaction: Jeffery, 2001jan01

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042 qmult 00500 2 4 2 moderate deducto-memory: helium shell flash defined
Extra keywords: CK-328,346, FK-493, Sun-question

53. "Let's play *Jeopardy*! For $100, the answer is: These short-time scale episodes of explosive helium shell burning in late stellar evolution eject material that become planetary nebulae."

What are ____________, Alex?

a) hydrogen shell flashes b) helium shell flashes c) supernovae d) hypernovae e) novae

SUGGESTED ANSWER: (b)

Wrong answers:
a) The answer say helium shell burning

Redaction: Jeffery, 2001jan01

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042 qmult 00600 1 4 4 easy deducto-memory: planetary nebula defined
Extra keywords: CK-329,346 FK-493, Sun-question

54. A planetary nebula is:

a) a **cloudy planet**.
b) a cloud that will coalesce into a **planet**.
c) a shell of gas thrown off by a dying star before it becomes a **protostar**.
d) a shell of gas thrown off by a dying star before it becomes a **white dwarf**.
e) a shell of gas thrown off by a dying star before it becomes a **galaxy**.

SUGGESTED ANSWER: (d)

Wrong answers:
a) This answer should be really out of it.

Redaction: Jeffery, 2001jan01

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043 qmult 00100 1 4 1 easy deducto-memory: white dwarf defined
Extra keywords: CK-346,347-5, Sun-question

55. White dwarfs are:

a) the compact remnants of stars. They are **NOT** burning nuclear fuel. They are **COOLING DOWN** forever.
b) giant red stars.
c) the compact remnants of stars. They are **STILL** burning nuclear fuel.
d) the compact remnants of stars. They are **NOT** burning nuclear fuel. But they are **HEATING UP** forever.
e) the compact remnants of stars. They are **NOT** burning nuclear fuel. They have **NEVER** been observed: they are merely predicted theoretically.

SUGGESTED ANSWER: (a)

Wrong answers:
e) They have to been observed.

Redaction: Jeffery, 2001jan01

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043 qmult 00300 2 1 4 moderate memory: black dwarf defined
Extra keywords: Sun-question

56. A black dwarf is:

a) a black hole.
b) a protostar hidden in a molecular cloud.
c) a protostar after emerging from its cocoon of gas and dust.
d) what a white dwarf becomes when it has cooled off to near absolute zero temperature.
e) a shell of gas thrown off by a dying star before it becomes a galaxy.

SUGGESTED ANSWER: (d)

Wrong answers:
e) The shell is a planetary nebula and a dying star doesn't become a galaxy.

Redaction: Jeffery, 2001jan01