Astronomy 101EA: 3rd Exam
2005 April 11 Monday

Instructions: There are 50 multiple-choice questions and the test is out of 50 marks. Choose the BEST answer, completion, etc., and darken fully the appropriate circle on the TABLE provided on page 2. Read all responses carefully. NOTE that long, detailed responses won’t depend on hidden keywords: keywords in such responses are BOLD-FACED capitalized.

This is a CLOSED-BOOK exam. NO cheat sheets allowed. Calculators are permitted. This a 75 minute exam. Remember your name (and write it down on the exam too). DO NOT discuss the test with those in any section who have not taken it.

You must show a photo id when handing in the exam.
NAME:

Answer Table for the Multiple-Choice Questions

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1. The surface (i.e., photosphere) temperature of an ordinary star can be determined from:

   a) the shape of its **NON-BLACKBODY** spectrum (particularly the location of the peak).
   b) an analysis of its **EMISSION** line spectrum.
   c) no known means.
   d) the shape of its approximately **BLACKBODY** spectrum (particularly the location of the peak) and/or an analysis of its **ABSORPTION** line spectrum.
   e) thermometers.

**SUGGESTED ANSWER:** (d)

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

**Redaction:** Jeffery, 2001jan01

2. The main sequence spectral star types are:

   a) ABCDEFGHIJKLMNOP.
   b) OBIWANKEN.
   c) OBAFGKM.
   d) OBGKMAF.
   e) OAGKMAO.

**SUGGESTED ANSWER:** (c) Remember the mnemonic: “Oh be a fine girl/guy kiss me.” Sometimes it is the only sensible thing to say.

**Wrong answers:**
   a) This was apparently the original old spectral type sequence (CK-286).
   b) Say it.

**Redaction:** Jeffery, 2001jan01

3. “Let’s play Jeopardy! For $100, the answer is: Each stellar spectral types is divided into these subtypes.”

   What are ____________, Alex?

   a) Ia, Ib, II, III, IV, and V   b) Chico, Groucho, Gummo, Harpo, Karlo, and Zeppo   c) Larry, Curly, and Moe   d) abcde...xyz   e) 0, 1, 2, … , 9

**SUGGESTED ANSWER:** (e)

**Wrong answers:**
   a) These are the luminosity classes.
b) These are the Marx brothers. Well Karlo actually never performed with the other brothers, but he was a well known writer on economic theory and used to supply his brothers with subversive subtexts for their gags.

c) They were low, very low.

Redaction: Jeffery, 2001jan01

4. “Let’s play *Jeopardy!* For $100, the answer is: It is a plot of stellar luminosity (or absolute magnitude) versus star temperature (or spectral type).”

What is a ________, Alex?

a) butterfly diagram  b) Hertz-Avis (HA) diagram  c) mass-luminosity diagram  d) Feynman diagram  e) Hertzsprung-Russell (HR) diagram

SUGGESTED ANSWER: (e)

Wrong answers:

a) This is used to plot sunspots.

d) I never really figured these out.

Redaction: Jeffery, 2001jan01

5. The main sequence on a Hertzsprung-Russell (HR) diagram is a curve (actually a narrow band) of _________ luminosity with increasing _________.

a) increasing; surface temperature  b) decreasing; surface temperature  c) constant; surface temperature  d) increasing; hydrogen content  e) decreasing; hydrogen content

SUGGESTED ANSWER: (a)

Wrong answers:

d) The hydrogen content is pretty constant for main sequence stars.

Redaction: Jeffery, 2001jan01

6. Main sequence stars, giants, supergiants, and white dwarfs all give rise to easily identifiable groups on a:

a) Hertzsprung-Russell (HR) diagram.  b) butterfly diagram.  c) Zipf plot.

d) Harley-Davidson (HD) diagram.  e) x-y diagram.

SUGGESTED ANSWER: (a)

Wrong answers:

c) There is a Zipf’s law—or so I recall.
d) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001jan01

7. The luminosity classes of stars are:

a) Chico, Groucho, Gummo, Harpo, Karlo, and Zeppo.  
b) bright, very bright, super-bright, unbelievable.  
c) 1, 2, 3, 4, 5, and 6.  
d) OBAFGKM.  
e) Ia, Ib, II, III, IV, and V.

SUGGESTED ANSWER: (e)

Wrong answers:

a) These are the Marx brothers. Well Karlo actually never performed with the other brothers, but he was a well known writer on economic theory and used to supply his brothers with subversive subtexts for their gags.

Redaction: Jeffery, 2001jan01

8. “Let’s play Jeopardy! For $100, the answer is: These objects appear on Hertzsprung-Russell diagrams and they are NOT assigned a luminosity class though reasonably they could be assigned to class VI.”

What are ____________, Alex?

a) luminous supergiants  
b) white dwarfs  
c) black holes  
d) green giants  
e) green dwarfs

SUGGESTED ANSWER: (b)

Wrong answers:

a) These at least are on HR diagrams, but they are luminosity class Ia.

Redaction: Jeffery, 2001jan01

9. On a log-log plot the mass-luminosity relation approximates a:

a) straight line that increases with mass.  
b) horizontal line.  
c) vertical line.  
d) quadratic curve.  
e) straight line that decreases with mass.

SUGGESTED ANSWER: (a)

Wrong answers:

e) Exactly wrong.

Redaction: Jeffery, 2001jan01

Extra keywords: CK-295
10. Two stars gravitationally bound to each other and orbiting their mutual center of mass constitute a:

   a) binary star system.  b) triple star system.  c) single star.  d) galaxy.  
   e) universe.

**SUGGESTED ANSWER:** (a)

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

**Redaction:** Jeffery, 2001jan01

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11. “Let’s play *Jeopardy!* For $100, the answer is: These are loosely-bound, irregularly-shaped groups of stars consisting of order 100 to 1000 stars and having size scales of order 4 to 20 pc.”

   What are ____________, Alex?

   a) singles  b) binaries  c) open clusters  d) globular clusters  
   e) galaxies

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
   a) As Lurch would say: “Aaaarh.”

**Redaction:** Jeffery, 2001jan01

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12. “Let’s play *Jeopardy!* For $100, the answer is: These are structures of a few to a few hundred stars and span of order 10 to 100 pc They are generally gravitationally unbound though gravitationally interacting.”

   What are ____________, Alex?

   a) singles  b) binaries  c) associations  d) globular clusters  
   e) galaxies

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
   a) As Lurch would say: “Aaaarh.”

**Redaction:** Jeffery, 2001jan01

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13. The life history of stars is known to us by:

   a) direct observations of the evolution of individual stars from the beginning of formation to final demise.

**Extra keywords:** Sunlife

**Redation:** Jeffery, 2001jan01
b) direct observations of the evolution of individual stars from the beginning of formation to final demise plus modeling.
c) direct observations of many stars at different stages of their evolution, some episodes of rapid individual star evolution, and modeling.
d) by modeling alone.
e) by sheer guesswork.

**SUGGESTED ANSWER:** (c) We only directly observe stars at a single stage in their evolution or in some episodes of rapid evolution: e.g., when they go supernovae or have some other explosive event.

**Wrong answers:**
e) “Sheer” and “guesswork” are correctly spelt anyway.

**Redaction:** Jeffery, 2001jan01

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14. Gas and dust in the space inside galaxies is:
   a) made of antimatter.  
   b) completely negligible for all purposes.
   c) the intergalactic medium (GSM).
   d) the interstellar medium (ISM).
   e) completely invisible.

**SUGGESTED ANSWER:** (d)

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

**Redaction:** Jeffery, 2001jan01

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15. 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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16. 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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17. “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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18. 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

040 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife
19. 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

040 qmult 01000 1 4 1 easy deducto memory: H II region defined
Extra keywords: CK-307,321,322-3
20. 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) a black hole.  d) a dark cloud.  e) He region.

SUGGESTED ANSWER: (a)

Wrong answers:
b) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001Jan01

040 qmult 01510 2 4 2 moderate deducto-memory: disk formation frequency
Extra keywords: CK-304, Sunlife
21. 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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22. “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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23. Atomic nuclei are made up of:

- a) protons and neutrons.
- b) protons and electrons.
- c) positrons and electrons.
- d) positrons and neutrals.
- e) protontrons 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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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 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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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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26. 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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27. 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 $4.16 \times 10^{15} \text{ J}$ 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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28. 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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29. 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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30. Hydrogen fusion does not happen near the surface of main sequence stars like the Sun because:

   a) the gravity is too high there.  
   b) the temperature and density are too low there.  
   c) there is insufficient hydrogen near the surface.  
   d) of comet
impacts.  e) of X-rays.

**SUGGESTED ANSWER:** (b) The answer should be deducible. (Deducible is a correct spelling.)

**Wrong answers:**
- a) I don’t think gravity can affect nuclear reactions in a direct way.
- c) The Sun is mainly hydrogen all the way through.
- d) Should be irrelevant to the vast bulk of the Sun.
- e) Red herring.

**Redaction:** Jeffery, 2001jan01

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31. The interior structure of a star is determined by observation, physics theory, and:
   a) back-of-the-envelope calculations.
   b) exact analytic math.
   c) guesswork.
   d) computer modeling.
   e) horseplay.

**SUGGESTED ANSWER:** (d)

**Wrong answers:**
- a) You can actually learn a lot from back-of-the-envelope calculations. They give order of magnitude estimates of some quantities and allow you do understand why the computer models come out the way they do.
- b) Very simplified stars do permit analytic treatments to a degree. These are useful in understanding what the computer is telling you.
- e) Horses have a rep.

**Redaction:** Jeffery, 2001jan01

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32. 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, $2 \times 10^{-7}$ 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
33. 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

34. Main sequence stars of low mass are mainly supported against collapse (≥ 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

35. 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

36. 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

37. 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

38. 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

39. 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

40. “Let’s play Jeopardy! For $100, the answer is: This mass which is theoretically known to be about $3 M_\odot$ is the upper limit on neutron star mass.”

What is the ____________ limit, Alex?
   a) Chandrasekhar  b) Oppenheimer-Volkov  c) Gamow  d) neutron star  e) white dwarf

SUGGESTED ANSWER: (b)

Wrong answers:
  a) This is the mass limit for white dwarfs.

Redaction: Jeffery, 2001jan01

41. “Let’s play Jeopardy! For $100, the answer is: He/she is the discoverer of special and general relativity.”

Who is ____________, Alex?

SUGGESTED ANSWER: (b)

Wrong answers:
  a) She was the discoverer of the period-luminosity relation for Cepheid variable stars (No-488) while working at Harvard College Observatory. Distance
determinations by Hubble using this relation established the extragalactic nature of the galaxies.
c) He observationally discovered the expansion of the universe and Hubble’s law.
d) Lemaître had theoretically deduced Hubble’s law prior to the observational discovery (No-524). He may not even have been the first to notice that such a law must hold in simple general relativity cosmology.
e) His mistaken observations of movement of the spiral arms of the spiral nebulae worked against the acceptance of the extragalactic nature of these objects (No-495).

Redaction: Jeffery, 2001jan01

**Extra keywords:** CK-362

42. Electromagnetic radiation that emerges from any gravity well experiences a:
   a) gravitational blueshift. b) gravitational greenshift. c) gravitational redshift. d) transcendental moment. e) senior moment.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
   e) All too soon, the author of this question will be experiencing these.

Redaction: Jeffery, 2001jan01

43. Black holes:
   a) certainly exist as all agree.
   b) do not exist, but they have caught the popular imagination and astronomers knowing a good thing when they have one keep writing about them.
   c) may exist: there is significant evidence for them, but in the opinion of some at least it is not conclusive.
   d) do not exist now, but will billions of years in the future.
   e) are redundant.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**
   e) A nonsense answer.

Redaction: Jeffery, 2001jan01

44. “Let’s play Jeopardy! For $100, the answer is: He/she is the discoverer of the analytically exact solution for the general relativity in massless-space outside of a non-rotating, chargeless, spherically symmetric mass distribution.”

Who is ____________, Alex?
a) Henrietta Swan Leavitt (1868–1921)  b) Karl Schwarzschild (1873–1916)
c) Albert Einstein (1879–1955)  d) Edwin Hubble (1889–1953)  e) Georges
Lemaître (1894–1966)

SUGGESTED ANSWER: (b)

Wrong answers:
a) She was the discoverer of the period-luminosity relation for Cepheid variable
stars (No-488) while working at Harvard College Observatory. Distance
determinations by Hubble using this relation established the extragalactic
nature of the galaxies.
d) He observationally discovered the expansion of the universe and Hubble’s
law.
e) Lemaître had theoretically deduced Hubble’s law prior to the observational
discovery (No-524). He may not even have been the first to notice that such
a law must hold in simple general relativity cosmology.

Redaction: Jeffery, 2001jan01

45. A black hole that has NO angular momentum is a __________ black hole and one
does have angular momentum is a __________ black hole.
   a) Kerr; Schwarzschild  b) Schwarzschild; Kerr  c) Einstein; Wheeler
d) Wheeler; Einstein  e) Tegmark; Wheeler

SUGGESTED ANSWER: (b)

Wrong answers:
e) Mark Tegmark is a high flyer who’ve I’ve even met.

Redaction: Jeffery, 2001jan01

46. The formula for the Schwarzschild radius is

\[ R_{\text{Sch}} = \frac{2GM}{c^2} \approx 2.9542 \left( \frac{M}{M_{\odot}} \right) \text{ km} , \]

where \( G = 6.6742 \times 10^{-11} \) (in MKS units) is the gravitational constant, \( M \) is the mass
of an object, \( c \) is the speed of light, and \( M_{\odot} = 1.9891 \times 10^{30} \text{ kg} \) is the mass of the Sun.
This formula follows from general relativity for a non-rotating, spherically symmetric
mass distribution, but it also accidently can be obtained by setting the escape velocity
equal to the speed of light in the Newtonian formula for the escape velocity from a
spherically symmetric mass distribution. According to general relativity if any object
is compressed within its Schwarzschild radius it:

a) will become Karl Schwarzschild.  b) may, but not necessarily will, become
a black hole.  c) must cease to exist.  d) must become a black hole.
e) will become a Schwarzschild.
SUGGESTED ANSWER: (d)

Wrong answers:
  a) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001Jan01

47. Compact X-ray sources in binary systems where the source seems to have MORE than $3M_\odot$ are:
   a) probably neutron stars.  b) black hole candidates.  c) white dwarfs.
   d) main sequence stars.  e) presidential candidates.

SUGGESTED ANSWER: (b)

Wrong answers:
  c) Probably not.
  e) This is the election year answer.

Redaction: Jeffery, 2001Jan01

48. Probably because of complex magnetic and electric field effects about rotating black hole candidates, these candidates exhibit:
   a) planes of glowing gas.  b) jets of glowing gas.  c) jets of ice water.
   d) stirrups of ice water.  e) dendritic patterns.

SUGGESTED ANSWER: (b)

Wrong answers:
  c) Liquid water can’t exist for long in the low pressure conditions of space.
  d) A nonsense answer.
  e) Dendritic means branching. This answers appears to belong to a question about lightning.

Redaction: Jeffery, 2001Jan01

49. These black hole candidates are found in the centers of large galaxies. They have masses of order $10^6 M_\odot$ to $10^9 M_\odot$. The name given to the kind of black holes these objects may be is:
   a) supermassive black hole.  b) primordial black hole.  c) Schwarzschild black hole.
   d) singularity black hole.  e) worst-case black hole.

SUGGESTED ANSWER: (a)

Wrong answers:
e) As Lurch would say: “Aaaarh.”

Redaction: Jeffery, 2001jan01

50. If the Sun instantaneously and without any other catastrophic effects collapsed to being a black hole, what would happen to the Earth?

a) Nothing: everything would be just as before including the Earth’s surface temperature.
b) The Earth would plunge into the solar black hole drawn by its sudden super-gravity.
c) The Earth would suddenly have escape velocity from the solar system and would fly off into space.
d) Because of strange quantum mechanical effects every possible event would happen to the Earth in infinitely many different parallel universes.
e) The Earth’s orbit would be unaffected, but the Earth’s surface temperature would soon fall too low to sustain life.

SUGGESTED ANSWER: (e)

Wrong answers:
b) The gravity field outside of the Sun’s current radius would be unaffected by the instantaneous collapse.
d) In the many world hypothesis something like this happens all the time: it doesn’t take a collapse of the Sun to being a black hole.

Redaction: Jeffery, 2001jan01