Introductory Astronomy

Homework 25: Black Holes Not to be handed in. Homework solutions are posted already.

1. "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

2. A postulate of special relativity is that the speed of light is:

   a) the same for all accelerated observers.
   b) different in different inertial frames.
   c) independent of the gravitational field.
   d) a constant and the same for all inertial-frame observers regardless of their motions.
   e) a constant and dependent on the phase of the Moon.

3. Einstein's general relativity (GR) is primarily a theory of:

   a) gravity, mass-energy, and spacetime. b) electromagnetism. c) light. d) Newtonian forces. e) atoms and nuclei.

4. 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.

5. 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.

6. "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)

7. The radius of the event horizon of a Schwarzschild black hole is the ____________ radius.

   a) Kerr-Schwarzschild b) ergoregion c) singularity d) Schwarzschild e) right

8. A black hole that is not rotating with respect to an inertial frame is a ____________ black hole and one that is so rotating is a ____________ black hole.

   a) Kerr; Schwarzschild   b) Schwarzschild; Kerr   c) Einstein; Wheeler   d) Wheeler; Einstein   e) Tegmark; Wheeler

9. The formula for the Schwarzschild radius is

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

   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 $M_\odot = 1.9891 \times 10^{30}$ kg is the mass of the Sun. This formula follows from general relativity for a 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.

10. Compact, short-wavelength X-ray sources in binary systems where the source seems to have **LESS** than $3\,M_\odot$ but more than $1.4\,M_\odot$ are:

    a) possibly neutron stars.   b) certainly black hole candidates.   c) white dwarfs.   d) main sequence stars.   e) presidential candidates.

11. 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.

12. 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 hole 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.

13. 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.
    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.

14. The more massive the star is, the faster it evolves in general. But black hole candidates in binary systems (which are presumably the compact remnants of ordinary stars) are sometimes less massive than their ordinary star companions. Resolve this paradox.

    a) The paradox can **NOT** be resolved: such systems are a complete mystery.

b) The black hole candidate progenitor was more massive than the companion, but lost significant mass in late stellar evolution and even more mass in the supernova explosion that is believed to have preceded the formation of the candidate.
c) Some mass always just disappears completely from the universe during black hole formation. This non-conservation of energy is a consequence of general relativity.
d) Companion stars always form much later than the candidate progenitors and are gravitationally captured by the candidate's super gravity field.
e) If you have just the right amount of inertial frame and a nearby quasar and add a couple of ad hoc hypotheses, then the masses work out right.