ASTRO 250

EXAM 1 - Sample

This exam has two parts. In **Part I**, indicate the best answer to the question directly on the question sheet. In **Part II**, write your answer in the space provided. Partial credit will be given if it looks like you are on the right track, or if you have the basic idea but do not give sufficient detail.

GOOD LUCK --- and RTFQ

USEFUL FORMULAE

distance=speed x time $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ $\gamma_G = \frac{1}{\sqrt{1-\frac{R_{Sch}}{d}}}$

$E=mc^2$ $\Delta l_{moving} = (1/\gamma) \times \Delta l$ $M_{sun}=2x10^{33}g$

$\frac{\text{stretch}}{\text{weight}} = \text{height[cm]} \times 10^7 \times \left[\frac{d}{R_{Sch}}\right]^{-3} \times \left[\frac{M}{M_{Sun}}\right]^{-2}$ $1\ L_{sun}= 4 \times 10^{33}$ erg/s

$c = 3x10^{10}$ cm/s = $3x10^5$ km/s $r_s = {}^{2GM}/_{c^2} = 3km \times (M/M_{sun})$ $\Delta t = \left(\sqrt{1-\frac{r_s}{R}}\right) \times \Delta t_\infty$

PART I: MULTIPLE CHOICE: 20 questions, 3 points each. Select the *best* answer to each of the questions below. Indicate your answer on this sheet.

1. If you were watching a star collapsing to form a black hole, the light would disappear because
   a) it is strongly redshifted.
   b) it is strongly blueshifted.
   c) it is all sucked into the black hole through the event horizon
   d) the color suddenly becomes black due to the rapid stellar contraction.
   e) of none of the above.

2. From an outsider's point of view, in watching a star collapse to form a black hole, the collapse would appear to take
   a) a minute or two
   b) a fraction of a second.
   c) a few hours.
   d) forever.
   e) not enough information given to answer

3. Which of the following is not a fundamental property of a black hole?
   a) mass
   b) electrical charge
   c) temperature
   d) spin
   e) all the above are fundamental properties of a black hole

4. Which of these is not a consequence of the assertion that the speed of light is the same as observed by any observer?
   a) time passes more slowly for fast-moving objects
   b) distances appear shorter on moving objects
   c) extra energy is needed to accelerate things already moving near the speed of light
   d) the rotation rate increases for fast moving objects
   e) all of the above are consequences of this assertion

5. The concept that there is no absolute time, postulated by Einstein, implies that
   a) two events that appear to occur simultaneously for one observer aren't necessarily simultaneous for a different observer
   b) two events that occur at the same time do not necessarily occur at the same point in space
   c) if there is a tie after nine innings, the teams play until one team has more runs at the end of extra innings
   d) light must follow a curved path through space
   e) light always travels in straight lines

6. The idea that we call Einstein's principle of equivalence asserts that
   a) within a frame, it is impossible to distinguish between an acceleration and the presence of gravity.
   b) the speed of light is measured to be the same by all observers, no matter how fast they are moving
   c) Time runs slower for faster moving objects
   d) $E=mc^2$
   e) F=ma

7. Which of the following are listed in order of increasing distance from the center of a slowly rotating black hole?
   a) Schwarzschild radius, photon sphere, ergosphere
   b) ergosphere, photon sphere, Schwarzschild radius
   c) event horizon, ergosphere, photon sphere
   d) photon sphere, ergosphere, event horizon
   e) none of the above are correct; the ergosphere and photon sphere have the same size

8. Approximately how many years will it take a black hole of 1 solar mass to evaporate by emission of Hawking radiation?
   a) 10 years
   b) 10^{10} years
   b) 10^{25} years
   d) 10^{65} years
   e) 10^{99} years

9. On what basis does Hawking connect the thermodynamic and psychological arrows of time?
   a) 'Time flies like an arrow' has several interpretations.
   b) The structuring of memory by the brain creates disorder in the universe because it consumes energy and generates heat.
   c) Hawking asserts that the human mind *controls* time.
   d) He doesn't connect them, and calls the relationship random.
   e) Huh?

10. Which of the following is not an *essential* ingredient for the time machine we discussed in class?
    a) a movable black hole
    b) a mechanism for preventing the collapse of a wormhole
    c) a way to accelerate to faster than the speed of light
    d) use of the principles of general relativity
    e) space travel

11. The event horizon of a black hole that results from the collapse of a $5M_{sun}$ body will be
    a) 5 km in radius
    b) 10 km in radius
    c) 15 km in radius
    d) 500 km in radius
    e) 10,000 km in radius

12. Which of the following statements is false?
    a) time travel - in one direction, at least - is easy
    b) travel into the future requires the use of black holes and technology currently not available
    c) in some limited applications, time reversal is allowed by the laws of physics
    d) the biological arrow of time is rooted in fundamental physics
    e) as far as we know, travel into the past requires the use of black holes and technology currently not available

13. The luminous, red star Betelgeuse is a single star with a mass of approximately $17M_{sun}$. What is its most likely eventual fate?
    a) it will produce a planetary nebula and a hot white dwarf.
    b) it will go on to star in the film adaptation of Lost in Space.
    c) it will produce a Type II supernova explosion, and leave behind a neutron star
    d) it will produce a Type I nova system
    e) it will produce a Type II supernova explosion, and leave behind a black hole

14. Stars remain stable in size for long times because of a balance between
    a) mass and luminosity
    b) pressure and gravity
    c) supply and demand
    d) temperature and density
    e) radius and brightness

15. The energy radiated during the initial phases of star formation comes from
    a) petroleum combustion.
    b) gas pressure.
    c) gravitational energy released by contraction.
    d) nuclear fusion.
    e) both b) and c) above.

16. A pulsar is an example of
    a) a black hole.
    b) a neutron star.
    c) Little Green Men sending an extraterrestrial signal
    d) a white dwarf.
    e) a protostar.

17. A _____ lives "forever" because electron degeneracy keeps gravity from further crushing it.
    a) leprechaun
    b) white dwarf
    c) neutron star
    d) supergiant
    e) black hole

18. A good analogy to the physical explanation of how a neutron star can appear as a pulsar is
    a) a blinking neon sign.
    b) a greenhouse.
    c) a metronome.
    d) a searchlight.
    e) a traffic light.

19. Einstein's famous equation, $E = mc^2$, says that
    a) energy is equivalent to mass.
    b) kinetic energy is determined by mass.
    c) the speed of light never changes.
    d) electromagnetism is the same as mass.
    e) energy is equivalent to light.

20. Which of the following fates await the Earth in the distant future?
    a) it will be gobbled up by the Sun when it first becomes a red giant
    b) it will survive until the Sun becomes a white dwarf, when the planetary nebula destroys it
    c) it will forever orbit the Sun, escaping destruction because of its relatively large orbit
    d) the Earth will spiral into the Sun when the Sun becomes a black hole
    e) it will eventually be destroyed when the moon's orbit decays and the moon crashes down

21. The rotation rate of observable neutron stars is about
    a) once per month
    b) once per minute
    c) once per second
    d) 10,000,000 times per second
    e) none of the above

22. You could tell that you were freely falling into a nonrotating black hole because
    a) you could watch your clocks slow down.
    b) you'd feel continually heavier.
    c) your red laser would turn green.
    d) the stars would contract into a narrow circle in the sky.
    e) as you approached the horizon, you'd sound funny when you talked..

23. According to Einstein, gravitational lensing is the result of
    a) time dilation.
    b) the gravitational redshift.
    c) the curvature of space.
    d) the Lorentz contraction.
    e) the presence of an event horizon.

PART II: SHORT ANSWER: Answer all questions in this part in the spaces provided

24 (7 points) Draw a space-time diagram of the collapse of a neutron star to form a black hole. Indicate the position of a) the original neutron star surface; b) the event horizon; c) the photon sphere; and d) beams of light emitted from the surface as it passes each of these points.

25. (7 points) a) Explain the idea of "cosmic censorship." b) What precisely is being censored? c) is there any way to blast through this and expose to the universe that which is being censored?

26. (6 points) a) Why is it safer to visit a 10^6 M_{sun} black hole than a 1 M_{sun} black hole?
b) Where in the Universe would you have to go to visit a massive black hole?

27. (9 points) Describe the last few moments in the life of a star as it forms a supernova.

a) Sketch its structure at the last instant that it would look like a normal star.

b) What is the 'energy crisis' that the inner part faces just before the end?

c) When the fireworks are over, describe what the remaining bit of the star at the center is like when the fireworks are over. How can we detect it?

28. (2 points) We are 1/3 done with Astro 250 - and just starting on cosmology. What one thing haven't we discussed yet that you really really want to hear about concerning stars, black holes, and time travel?