Name: ....

ASTRONOMY 1102 – 1

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Third Test – Friday April 9, 1999

Part I – Multiple Choice questions (5 pts/question; total = 60 pts)
Identify the correct answers by placing a check between the brackets [ ]. Check **ALL** correct answers in the questions identified by a *.

*1) Some true statements about pulsars:
[x] They are born spinning fast and they slow down.
[x] Some old pulsars do have short periods.
[ ] They never stop spinning and emitting pulsar radiation. *FALSE: pulsar radiation stops*
[x] Several binary pulsars are known.
[ ] The *orbital* period of "the" binary pulsar PSR 1913+16 is getting longer. *FALSE: it's getting shorter*

2) The energy generated in a massive main sequence star is produced *mostly* by
[ ] Helium burning.
[ ] the proton–proton chain. FALSE: dominates in the sun and lighter stars
[x] the CNO cycle.
[ ] gravitational contraction.
[ ] convection.

3) A neutron star is
[x] the endpoint of the evolution of massive stars ($50M_\odot > M > 8M_\odot$).
[ ] supported by thermal pressure, with prominent hydrogen lines.
[ ] supported by electron degeneracy, with no steady nuclear burning.
[ ] a large star with hydrogen shell burning.
[ ] produced only when stars less massive than the sun die.

4) Some protostars never develop central temperatures high enough for H burning
[ ] because they are too massive.
[ ] so they remain cool and are known as red dwarfs.
[ ] because they are too large and cool.
[ ] so they just cool and become black dwarfs.
[x] because they do not have enough mass and become brown dwarfs.

*5) The post-Main-Sequence evolution of a 25 $M_\odot$ star
[ ] is similar to the sun's but an iron white dwarf is formed.
[x] goes through several blue and red supergiant stages.
[x] produces a core collapse supernova of type II.
[x] leaves behind a neutron star.
[ ] leaves behind a black hole.

6) The rapid advance of the perihelion of PSR1913+16 is
   [ ] predicted by Newton's theory of gravity.
   [ ] predicted by Einstein's Special Relativity.
   [ ] a consequence of planetary perturbations.
   [x] in very good agreement with Einstein's General Relativity.
   [ ] due to the pulsar emission mechanism.

7) A WD accreting H-rich material from a companion
   [ ] undergoes recurrent supernova explosions when H fuses to He.
   [ ] explodes when the triple alpha process starts.
   [x] undergoes recurrent nova explosions when H fuses to He.
   [ ] undergoes rapidly recurrent X-ray bursts.
   [ ] produces a core-collapse supernova.

8) A Main sequence star of 5 $M_\odot$
   [ ] burns hydrogen for a longer time than the sun. *FALSE: burns faster*
   [x] dies ejecting a planetary nebula and becoming a carbon WD.
   [ ] goes through the He flash at the tip of the RGB.
   [ ] dies in a supernova explosion becoming a neutron star.
   [ ] belongs to luminosity class III.

9) An X-ray binary in which the compact accreting object has a mass of $8M_\odot$ is
   [ ] a cataclysmic variable (WD and a normal companion).
   [ ] a neutron star binary (NS and a normal companion).
   [x] a black hole candidate (BH and a normal companion).
   [ ] a binary pulsar.
   [ ] a black hole–black hole binary or binary BH.

10) The following processes in a core–collapse SN lead rapidly to a NS
   [ ] CNO cycle.
   [ ] p–p chain and He flash.
   [x] photodisintegration, neutronization and bounce.
   [ ] alpha–process, s–process and r–process.
   [ ] convection, conduction and radiation.

11) A carbon–Detonation Supernova (Type Ia) occurs when
   [ ] the iron core collapses.
   [x] a WD exceeds the Chandrasekhar Mass by accretion or merger.
   [ ] hydrogen is exhausted in the core
   [ ] the triple alpha process produces carbon
   [ ] a star becomes a red giant.

12) One true statement about stellar evolution:
   [ ] all stars, regardless of their mass, become red giants.
   [ ] all stars when they die produce a WD.
   [x] stars with masses exceeding 8 $M_\odot$ produce NS or BH
   [ ] nothing of interest happens after a WD is formed.
   [ ] stars with masses $M < 8M_\odot$ die as black holes.

Part II – Problems (10 pts/problem; total = 40 pts) **NO CALCULATORS!**

Problem 1: Describe in words or sketch roughly in the correct order but without worrying about the scale and dimensions, the internal structure of a massive star before core collapse. (You may refer if you wish to the periodic table shown on page A4)

An inert – non burning – core of iron Fe, containing also Ni and Co at the center surrounded by shells in which nuclear burning is still going on. These burning shells are in order, from the inside outward: Si, Mg, Ne, O, C, He, and H. Finally the H burning shell is surrounded by a convective, non burning Hydrogen **envelope**.

Problem 2: Answer the following questions about **white dwarfs:**

a) They are supported against their own gravity by the pressure of *degenerate electrons*

b) They have a radius of approximately *one Earth radius*

c) They are the endpoint of evolution of *lightweight Main Sequence stars* $M < 8M_{\odot}$

d) The maximum mass a WD can have is *the Chandrasekhar Mass, 1.4* $M_{\odot}$.

e) Before they form, they eject a *Planetary Nebula*

$R_S = 3(M_{BH}/M_{\odot})$ km, $\quad 1.585^2 = 2.512 \quad 1.585^3 = 4. \quad 1.585^4 = 6.3$

$\lambda = cT \quad \lambda f = c \quad \frac{\Delta\lambda}{\lambda_{\rm emi}} = \frac{\lambda_{\rm obs} - \lambda_{\rm emi}}{\lambda_{\rm emi}} = \frac{v}{c} \quad \lambda_{\rm obs} = \lambda_{\rm emi} + \Delta\lambda$

1 pc = 3.26 LY $\quad d({\rm pc}) = 1/p({\rm arcsec}) \quad \lambda_{\max} \propto 1/T \quad E \propto T^4 \quad Flux \propto 1/d^2$

$L \propto R^2 T^4 \quad \sqrt[5]{10} = 1.585 \quad \sqrt[5]{100} = 2.512$ On the MS: $L \propto M^3$, $R \propto M$

Problem 3: Suppose that you are in a powerful rocket that allows you to go close to a black hole and remain there stationary without falling in. Let's suppose that your feet point in the direction toward the center of the BH ("below") so that "above" means overhead. You look at the black hole and you look at the starry sky. Where are you with respect to the event horizon and the photon radius if

a) half the sky is total blackness ("below") and all the stars in the sky, some multiply imaged, including those "behind" the BH, are seen in the other half ("above").

Half the sky being black, means that no light comes from there or that all light sent in those directions gets absorbed by the BH. You can see stars in the other half or light sent in those directions can escape to infinity. Either of these arguments shows that the exit cone is 90 degrees and therefore you are at the photon sphere or photon radius.

b) total blackness almost surrounds you except a small circular patch overhead where you can see all the stars in the sky, some multiply imaged.

In this case the exit cone is less than 90 degrees, so you must be somewhere between the horizon and the photon sphere. The smaller the exit cone the closer you are to the event horizon. So, in conclusion, you must be outside the event horizon but close to it.

Problem 4: A SN of type Ia is seen in a distant galaxy at a peak magnitude of 17. Knowing that the absolute magnitude of this kind of SN peaks at $M = -19$, estimate the distance to the galaxy in Mpc.

The distance modulus is $m - M = 17 - (-19) = 17 + 19 = 36$. *Since* $36 = 35 + 1$, *the distance must be*

$$d = (1.585)^1 \times 10^{(35/5)} \times 10pc \approx 1.6 \times 10^8 pc.$$

Expressing d in Mpc,

$$d \approx 160Mpc.$$

$_1H^1$							$_2He^4$
$_3Li^7$	$_4Be^9$	$_5B^{11}$	$_6C^{12}$	$_7N^{14}$	$_8O^{16}$	$_9F^{19}$	$_{10}Ne^{20}$
$_{11}Na^{23}$	$_{12}Mg^{24}$	$_{13}Al^{26}$	$_{14}Si^{28}$	$_{15}P^{31}$	$_{16}S^{32}$	$_{17}Cl^{35}$	$_{18}Ar^{40}$