PHY 490 Exam II **Name** _____

Instructions:

- Place your name on all of the pages.
- Do all of your work in this booklet. Do not tear off any sheets.
- Show all of your steps in the problems for full credit.
- Be clear and neat in your work. Any illegible work, or scribbling in the margins, will not be graded.
- Put a box around your answers when appropriate..
- If you need more space, you may use the back of a page and write *On back of page #* in the problem space or the attached blank sheet. **No other scratch paper is allowed.**

Try to answer as many problems as possible. Provide as much information as possible. Show sufficient work or rationale for full credit. Remember that some problems may require less work than brute force methods.

If you are stuck, or running out of time, indicate as completely as possible, the methods and steps you would take to tackle the problem. Also, indicate any relevant information that you would use. Do not spend too much time on one problem. **Pace yourself.**

Pay attention to the point distribution. Not all problems have the same weight. Be careful to note **units** and use an appropriate number of **significant digits.**

Page	Pts	Score
1	**17**	
2	**13**	
3	**14**	
4	**9**	
5	**17**	
Total	**70**	

Constants: $L_0 = 78.7 L_{sun}$, $f_0 = 2.53\times10^{-8}\,\mathrm{Wm^{-2}}$, $M_{sun} = 1.989\times10^{30}\,\mathrm{kg}$,
$M_{earth} = 5.98\times10^{24}\,\mathrm{kg}$, $1\,Mpc = 3.086\times10^{22}\,\mathrm{m}$, $1\,AU = 1.496\times10^{8}\ \mathrm{km}$
$G = 6.673\times10^{-11}\,\mathrm{m^3kg^{-1}s^{-2}}$, $h = 6.626\times10^{-34}\,\mathrm{Js}$, $\varepsilon_{c,0} = 8.3\times10^{-10}\,\mathrm{Jm^{-3}}$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{\kappa c^2}{R_0^2 a^2}$$

Bonus: If the apparent magnitude of the star in Problem 6 is 2.50, what is the luminosity distance?

PHY 490 Exam II **Name** _____

1. (4 pts) Give the Benchmark Model values:
   a. $\Omega_{r,0}$ = _____
   b. $\Omega_{m,0}$ = _____
   c. $\Omega_{\Lambda,0}$ = _____
2. (9 pts) Answer the following:
   a. _____ assigned the original magnitude range for stars.
   b. The binding energy of deuterium is _____.
   c. After studying the Coma cluster, _____ introduced the idea of dark matter.
   d. The Cepheids were first classified by _____ as standard candles.
   e. _____ was the first to measure red shifts of nebulae.
   f. The _____ model was proposed by Fred Hoyle and others in the late 1940s in competition with the Big Bang Model.
   g. A flat, matter dominated universe will end in a _____.
   h. The _____ gives the maximum mass of a stable white dwarf star at 1.4 M_{sun}.
   i. _____ is a term used for future null infinity.

3. (2 pts) The equation of state takes the form $P = w\varepsilon = w\rho c^2$. What is w for
   a. A photon gas? _____
   b. Hydrogen gas? _____

4. (6 pts) Recall that $a(t) \approx 1 + H_0(t - t_0) - \frac{1}{2} q_0 H_0^2 (t - t_0)^2$.

   a. In terms of a determine

      i. H_0

      ii. q_0

5. (3 pts) A star has luminosity $L = 250 L_{sun}$. What is the absolute magnitude?

6. (9 pts) Consider an empty, negatively curved universe.

   a. Find $a(t)$ in terms of t and $t_0 = \frac{R_0}{c}$..

   b. Find the proper distance $d_p(t_0)$.

   c. If the measured red shift for a particular star is given as 2.0, then determine $d_p(t_e)$ as a multiple of the Hubble distance.

7. Hubble first obtained H_0 as 550 km s^{-1} Mpc^{-1}. What would this give for the age of the universe in years?

8. (3 pts) Find $a(t)$ for a flat, Λ - only, universe.

9. (3 pts) Consider a positively curved universe which contains only radiation. Find *a(t).*

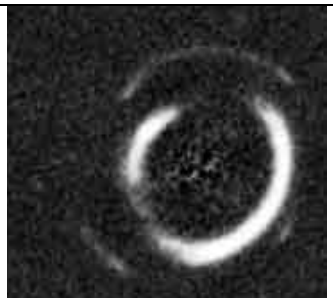
10. (5 pts) Fill in the blanks in this timeline (We only know a few now.).

Time	a	Temp (K)	z	Event
13.5 Gy	_____	2.7		Now
9.8Gy	0.75			Λ -Dominant
950 Myr			6	
300 Myr			14	Reionization
0.35 Myr			1100	_____
0.35 Myr		3000		Decoupling
0.24 Myr		3740	1370	_____
0.047 Myr	0.00028		_____	Photoionization
_____		7.6×10^8		BBN

PHY 490 Exam II **Name** _____

11. (6 pts) Describe these pictures as specifically as you can. (Some you can now.)

_____



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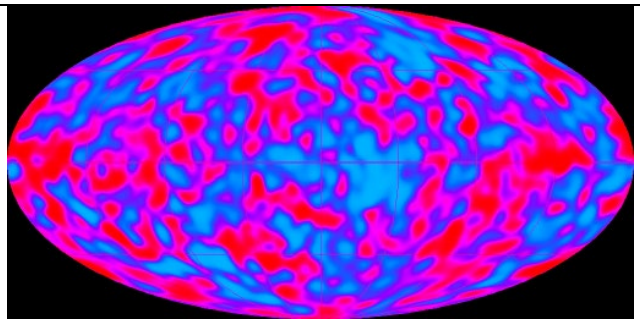

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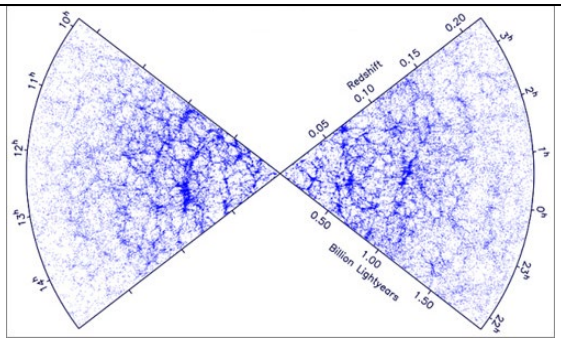

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12. (3 pts) Rewrite the Friedmann equation at the current time in terms of H_0 and Ω_0.

13. Use *G*, $\hbar$ and *c* to construct a characteristic length, the Planck length.

14. (9 pts) Consider an empty, negatively curved universe.

a. Find $a(t)$ in terms of t and $t_0 = \frac{R_0}{c}$..

b. Find the proper distance $d_p(t_0)$.

c. If the measured red shift for a particular star is given as 2.0, then determine $d_p(t_e)$ as a multiple of the Hubble distance.

15. For the Sun

a. From its radius and distance from the Earth (in au), compute the angular diameter and solid angle.

b. Given the Luminosity of the Sun, find the Sun's flux and brightness at the Earth.

16. A star radiates with a surface temperature of 7000 K. What is the peak wavelength emitted assuming it is blackbody radiation.

17. Consider a ten solar mass star with a radius ten times that of the sun. Find the escape velocity and velocity needed to orbit the star at 1 au.

18. An asteroid is 4 au's from the sun. What is the period of its motion?

19. (6 pts) On the plot below indicate the solutions corresponding to positive, zero, and negative curvature for a matter dominated FLRW spacetime. How does each universe end?