You may use 1 sheet of notes during this test. You may not have any books or other notes. Some of the information in the table below is not used on this test.

Write brief answers. Your time is limited, and the graders do not like to read answers that address off-topic ideas.

You may pick up the exam next year in room 3260. If you want your grade by e-mail, send me an e-mail at Loh@msu.edu.

Good luck.

Name	
PID	
Signature	
1	/9
2	/13
3	/7
4	/6
5	/6
6	/4
7	/11
8	/9
Total	/65

Star	App mag	Abs mag	Spectral type	Distance (pc)
Sun	–26.74	4.83	G2	1/200,000
Sirius	–1.45	1.41	A1	2.7
Canopus	–0.73	–4.7	F0	60

Kepler's 3rd Law	$P^2 = R^3/M$ (in AU, year, & M_{sun})	Hubble's Law	$v = H D$
	$M = 233\ v^2\ R$ (in parsec, km/s, & M_{sun})	Wien's Law	$\lambda_{peak}\ T =$ constant
Redshift	$z = 1/a - 1$; $a = 1/(1+z)$	Hubble's Constant	70 km/s/Mpc
	$v = c\ z$;	Speed of Light	300,000 km/s
	$v = c\ (\lambda_{rec}/\lambda_{emit} - 1)$		
Present temperature of radiation from Big Bang	2.728 K	Parsec	3.09×10^{13} km
		AU	1.50×10^{8} km
		Year	3.16×10^{7} s

1. Motions. Write very brief answers.
    a. (2 pts.) Explain why the sun moves with respect to the stars.
    b. (2 pts.) Explain why the planets sometimes moves east to west with respect to the stars, which is opposite the way the sun moves.
    c. (2 pts.) Explain why Mars moves east to west with respect to the horizon.
    d. (3 pts.) Copernicus's theory displaced Ptolemy's theory. How did Ptolemy explain each of these three motions?
2. About the sun. Write very brief answers.
    a. (2 pts.) At the present time, how does the sun produce energy? What is used up and what is created?
    b. (1 pt.) What is the approximate age of the sun and earth?
    c. (1 pts.) What will the sun become when it completely exhausts its fuel? (1 pt.) How big will it be? (1 pt.) What will prevent gravity from making it collapse?
    d. (2 pts.) The sun is losing more mass than can be accounted with the loss of protons, neutrons, and electrons. Explain how that is possible.
    e. (2 pts.) What elements were present in the material from which the first stars were made? (1 pt.) Was the material from which the sun was made different or the same in composition? (2 pts.) Explain.
3. Suppose the main-sequence star Sirius and the sun swapped places and the path (not the speed) of the earth remains the same. See table on the front.
    a. (2 pts.) Would daytime be brighter or fainter? Why?
    b. (3 pts.) Find the new apparent magnitude of Sirius?
    c. (2 pts.) Would the year be longer or shorter? Explain.
4. The first stars formed when the expansion parameter of the universe was 1/10. (That means the universe has expanded by a factor of 10 since that time.)
    a. (2 pts.) Compute the temperature of the radiation from the Big Bang at this time.
    b. (2 pts.) One of these first stars emitted some light at a wavelength 1215 Å. At what wavelength do we observe this light?
    c. (2 pt.) Was the distance between the proto Milky Way and the proto Andromeda Galaxy 70 kpc when the first stars formed? The present distance between the Milky Way and Andromeda is 700 kpc, and it is moving at 200km/s toward us. Explain.
5. (2 pts.) What did astronomers observe that indicated the presence of a black hole in the center of our galaxy? (2 pts.) How did they deduce the mass of the black hole from these observations? (2 pts.) What evidence indicated the size of the mass was small?
6. In 1962 Penzias and Wilson discovered radiation that was "isotropic and free of seasonal variations." That it was isotropic was used to argue that the radiation was from the Big Bang. Simplicio says, "In 2003, the WMAP satellite found that the radiation is not isotropic. Therefore the radiation is not from the Big Bang." (1 pt.) Is Simplicio correct? Explain. (3 pts.)
7. A supernova exploded when the expansion parameter was ½.

a. (1 pt.) If the universe has more mass, would its flux be fainter or brighter? (3 pt.) Explain.

b. (2 pt.) What two parameters of the supernovae were measured to measure the mass density of the universe?

c. (3 pts.) State the results of the measurements.

d. (2 pts.) What was discovered? Why was this one of the most significant discoveries in cosmology?

8. Dark matter

a. Explain the evidence for dark matter in galaxies. (2 pts) What was measured? (4 pts.) What in the measurements indicate the presence of dark matter?

Planet	Period (yr)	Semi-major axis (AU)
Real Solar System		
Earth	1.00	1.000
Mars	1.88	1.523
Solar system around Nus		
Htrae	1.00	1.000
Sram	0.94	1.523

b. (3 pts.) Imagine a star Nus with two planets Htrae and Sram. The periods and semi major axes of Nus' planets and the Sun's planets are shown in the table. Nus has no other planets and no other visible objects. Does Nus have dark matter? Explain.