

You may use one sheet of notes. You may not use books or additional notes.

Do the easy questions first. Then go back to the harder ones.

If you need the result of part (a) to do part (z) but cannot do part (a), explain how you would do part (z) if you had the answer to part (a).

Name	
PID	
1	/ 10
2	/ 6
3	/ 6
4	/ 6
Total	/ 28

Hubble's constant is 60(km/s)/Mpc.

The speed of light is 300,000km/s.

The present temperature of the radiation from the Big Bang is 2.7K.

Table 1. Spectral lines of hydrogen and oxygen and their laboratory wavelengths. OII means oxygen with one electron removed, and OIII is oxygen with two electrons removed.

<i>Line</i>	<i>Wavelength \AA</i>	<i>Line</i>	<i>Wavelength \AA</i>
H α	6562	OII	3727
H β	4861	OIII	5007
H γ	4340		
H δ	4101		
H ϵ	3970		

1. Astronomers measured the spectrum of galaxy X. They found the OIII line to be spread over a range of wavelengths. The peak is at 7000 \AA , and the light is spread between 6995 \AA and 7005 \AA .
 - a. (2 pts.) Compute the redshift z of galaxy X.
 - b. (2 pts.) What does the spread in the wavelength of the OIII line tell us about galaxy X?
 - c. (2 pts.) What is the distance D to galaxy X?
 - d. (2 pts.) At the time the light was emitted from galaxy X, what was the distance D_1 to galaxy X?
 - e. At the time the light was emitted from galaxy X, was the temperature T_1 of the radiation from the Big Bang cool enough that water freezes (273K)? (2 pts.) Explain.
2. Simplicio says.
 - a. (3 pts.) Simplicio says, "Almost all other galaxies move away from us. We in the Milky Way are lucky to be at the center of the universe." Are we lucky to be at the center of the universe? Explain.
 - b. (3 pts.) Simplicio says, "Everything in the universe obeys Hubble's Law." In this case, Simplicio is wrong. What is an example of something that does not obey Hubble's Law? Explain how it was able to violate Hubble's Law.
3. (6 pts.) A small fraction of the nuclei in the sun and solar system was made in other stars, but most was made when the universe was 3 minutes old. Where could you collect sample A of material primarily made in stars and where could you collect sample B of material primarily existing when the universe was 4 minutes old? What in your two samples is material made in stars and what existed when the universe was 4 minutes old? You must write an explanation to get any credit.
4. Nucleosynthesis in the Big Bang.
 - a. (4 pts.) Why does the ratio of neutrons to protons, n/p , fall slowly from 1:1 to 1:7 as the universe ages from 0.001s to 3min, and then flat-line at 1:7.
 - b. (2 pts.) If helium could form at 0.001s, how much helium and how much hydrogen would form from 16 nucleons? (A nucleon is a proton or a neutron.)