ASTRONOMY 143: The History of the Universe
Professor Barbara Ryden

PRACTICE MINI-EXAM
WITH SOLUTIONS

Short-Answer Problems

1) Which has the greater energy: a photon of infrared light or a photon of ultraviolet light?

ULTRAVIOLET light has the greater energy per photon.

2) Which is longer: a sidereal day or a solar day?

The SOLAR day is 4 minutes longer than the sidereal day.

3) Arrange the following objects in order of increasing mass: brown dwarf, Jupiter, Sun, Earth.

The EARTH is lowest in mass, followed by JUPITER, a BROWN DWARF, and the SUN.

4) Two stars have the same luminosity. One star has a parallax of 0.1 arcseconds. The other has a parallax of 0.5 arcseconds. Which star has the greater flux?

The star with the LARGER PARALLAX (0.5 arcseconds) is closer, and thus has a greater flux.

5) If the density of the universe were greater than the critical density, would the universe be negatively curved, positively curved, or flat?

The universe would be POSITIVELY CURVED.

6) A newly formed zircon crystal contains 1000 uranium-238 atoms. How many uranium-238 atoms will be left after two half-lives?

There will be 250 atoms left.

7) Which contributes most to the average density of the universe: dark energy, dark matter, or ordinary matter?

DARK ENERGY contributes the most.

8) How long after the Big Bang did the first galaxies form? The first galaxies formed about 750 MILLION YEARS after the Big Bang.

9) The star named "Gliese 710" is at a distance $d = 15\,\text{parsecs}$ from the Sun.

a) What is the distance from the Sun to Gliese 710, measured in kilometers?

The distance in kilometers is

$$d = 15\,\text{pc} \times \frac{3.1 \times 10^{13}\,\text{km}}{1\,\text{pc}} = 4.65 \times 10^{14}\,\text{km}\ .$$

b) From the Doppler shift of Gliese 710, it is known to be coming closer to the Sun, with a radial velocity $v = -24\,\text{km/sec}$. If Gliese 710 is moving *straight* toward the Sun, how many years will it be until they collide?

The time in seconds will be

$$t = \frac{d}{v} = \frac{4.65 \times 10^{14}\,\text{km}}{24\,\text{km/sec}} = 1.9375 \times 10^{13}\,\text{sec}\ .$$

Converted to years, this time is

$$t = 1.9375 \times 10^{13}\,\text{sec} \times \frac{1\,\text{year}}{32{,}000{,}000\,\text{sec}} = 605{,}000\,\text{years}\ .$$

10) Ordinary matter provides 4% of the critical density of the universe.

a) What is the average density of ordinary matter in the universe, given in units of kilograms per cubic meter?

Since the critical density is $\rho_{\rm crit} = 10^{-26}\,{\rm kg/m^3}$, the density of ordinary matter is

$$\rho_{\rm ord} = 0.04\rho_{\rm crit} = 0.04 \times 10^{-26}\,{\rm kg/m^3} = 4 \times 10^{-28}\,{\rm kg/m^3}\ .$$

b) Suppose that the ordinary matter consisted entirely of regulation bowling balls, each with a mass $M_{\rm bb} = 7\,{\rm kg}$. How many bowling balls, on average, would there be in one cubic astronomical unit (AU) of space?

The number of bowling balls per cubic meter would be

$$n_{\rm bb} = \frac{\rho_{\rm ord}}{M_{\rm bb}} = \frac{4 \times 10^{-28}\,{\rm kg/\,m^3}}{7\,{\rm kg}} = 5.714 \times 10^{-29}/\,{\rm m^3}\ .$$

Since $1\,{\rm AU} = 1.5 \times 10^{11}\,{\rm m}$, the volume of a cube 1 AU on a side will be

$$V = 1\,{\rm AU}^3 \times \left(\frac{1.5 \times 10^{11}\,{\rm m}}{1\,{\rm AU}}\right)^3 = 3.375 \times 10^{33}\,{\rm m^3}\ .$$

Thus, the number of bowling balls in a cube 1 AU on a side would be

$$N = n_{\rm bb}V = (5.714 \times 10^{-29}/\,{\rm m^3}) \times (3.375 \times 10^{33}\,{\rm m^3}) = 193{,}000\ .$$

That's not a lot of bowling balls to be drifting around in such a big cube.