8.9 Exercises

Cosmic Distances

Ex 8.1. You shoot a radar towards the moon. The signal comes back 2.4 sec later. How far is the Moon?

Ex 8.2. The parallax angle to a star is 0.01 arcsec. How far is the star in (a) pc , (b) ly, (c) m?

Luminosity of Stars

Ex 8.3. What is the flux of Sun at the surface of Jupiter? Data: Luminosity of Sun, $L_\odot = 3.846 \times 10^{26}$ W, distance of Jupiter from Sun $= 7.75 \times 10^{11}$ m.

Ex 8.4. The flux of Sun at the surface of Earth is 1.361 kW/m^2. What will be the flux Sun at a point half way to the Sun?

Ex 8.5. Deduce the mass of the Sun from the orbital period (1 year) and radius $(1.5 \times 10^{11}$ m) of the orbit of Earth.

Ex 8.6. In a binary star system, one of the stars is a massive black hole B and the other is a main-sequence star S. The star S has moves around B with a speed of $10,000$ km/s and has a period of revolution of 1 week. Assuming a circular orbit for S, find the mass of the black hole.

Ex 8.7. The absolute magnitude of a star is -10. The apparent magnitude on Earth is measured to be 5. How far is the star?

Ex 8.8. The temperature of a star is found to be 6500 K. What is the flux at the surface of the star?

Ex 8.9. A star has luminosity of $L = 2.5 \times 10^{30}$ W. The spectrum of the light from the star has a maximum at 450 nm but the spectral lines are shifted by a redshift $z = 0.5$. (a) What is the maximum of the spectrum emitted by the star? (b) What is the temperature of the star? (c) What is the radius of the star?

Ex 8.10. The supernove SN1987A occurred approximately 51.4 kpc from Earth. Its brightness peaked with an apparent magnitude of about 3. (a) What was the luminosity of the supernova SN1987A at the peak? (b) How does it compare with the luminosity of the Sun?

Ex 8.11. The Sun is currently in orbit about 8 kpc from the center of the Galaxy with the orbital speed of 220 km/s. How many times the Sun has gone around the center of the glaxy since its birth if it was formed around 4.6 billion years ago?

Hubble's Law

Ex 8.12. Find the distances to galxies recessional velocities are (a) $\frac{c}{50}$, (b) $\frac{c}{10}$, (c) $\frac{c}{2}$?

Ex 8.13. The red shift of a galaxy is observed to be $z = 0.1$. (a) What is the recession speed of the galaxy? (b) How far away is the galaxy?

Ex 8.14. A distant galaxy has strong hydrogen spectral lines. The line for H_α is found to be at 7560 Årather than 6562.8 Åseen from a hydrogen atom in the lab. (a) What is the red shift of the galaxy? (b) How fast is the galaxy receding? (c) How far is the galaxy from Earth?

Ex 8.15. A Cepheid star has period of 5 days and apparent brightness of +10. How far is the star?

Ex 8.16. Astronomers find that if all Type Ia supernovae were at a distance of 100 kpc, they would have a peak magnitude of +1. What is the absolute magnitude M of Type Ia supernova?

Ex 8.17. The light curves for type Ia supernovae are a consistent maximum absolute magnitude M of -19.3. In a far away galaxy a type Ia supernova appears all of sudden. The light curve of the supernova shows that luminosity peaks at the apparent magnitude -9.3. How far away is the galaxy that contains the supernova?

Einstein's Gravitation

Ex 8.18. A neutron star has a mass of 1.5 $M_\odot$, where $M_\odot$ is mass of the Sun, and the radius $R = 1.5$ km. (a) Find the Schwarzschild radius of the neutron star. (b) Is a point at the Schwarzschild radius inside the neutron star?

Ex 8.19. Light path has the event distance element, $ds = 0$. Consider one-dimensionsal case in which set $d\theta = 0$ and $d\phi = 0$ in the Schwarzschild metric. (a) Solve $ds = 0$ for the light path when light is at a point $r > r_s$. (b) What do you expect for $ds = 0$ if the space is flat?

The Big Bang Cosmology

Ex 8.20. A π^0 meson of rest mass energy is 135 MeV/c^2. In the early universe temperature was high enough that it contained photons of energy such that two photons produced one π^0 meson. (a) What must be the minimum energy of each photon so that π^0 meson can be produced? (b) What must have been the temperature of the Universe at that time? (c) In which age of the Universe did this temperature occur?

Ex 8.21. What was the age (t value) of the Universe when the temperature of the Universe was (a) 10^{15} K, (b) 300 K?

Ex 8.22. The distances to some well-known galaxies are: (a) distance to Large Magellanic Cloud is 50 kpc, (b) distance to Andromeda Galaxy is 780 kpc, and (c) the distance to Messier 83 is 4.5 Mpc. The sodium D line in the lab is seen at 5890 Å. What will be the wavelengths of this spectral line in the light from these galaxies?

Ex 8.23. The figure below shows the absorption spectrum from the Andromeda Galxy, also called M31. The spectrum shows two lines that can be attributed to calcium. Use the graph to find the recession speed of the galaxy with respect to Earth. [Fig. credit: NASA]
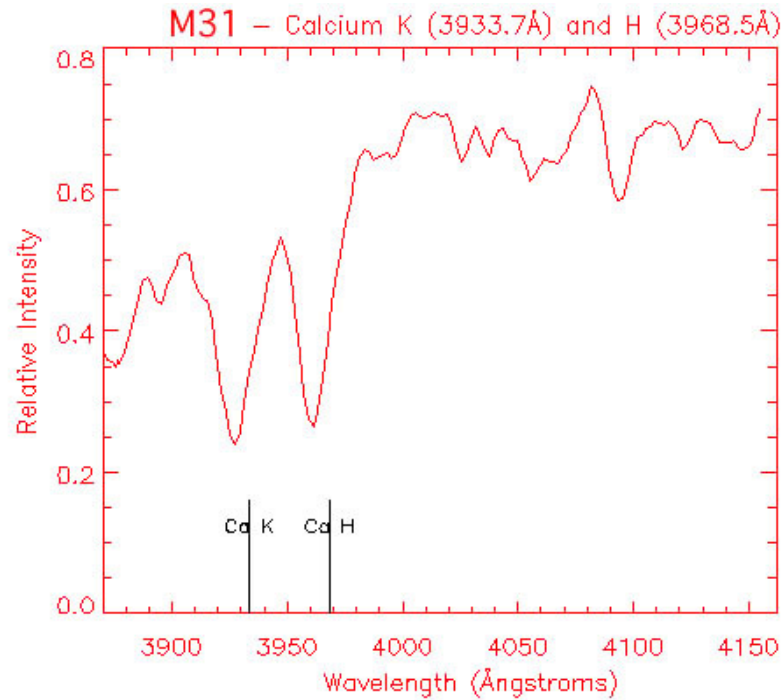
Ex 8.24. (a) Compute the threshold energy for the following reaction.

$$p + e^- \rightarrow p + \nu_e.$$
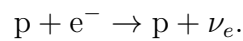
(b) At what time in the universe would the temperature will be high enough for this reaction to occur?