Often the biggest challenge to doing homework is to figure out the detailed steps. A more important task is to think about what you learned. After doing a problem, identify the big ideas and the details. If you cannot identify what you learned immediately after doing a problem, you will certainly not be able to recall the ideas on a test.

1. **Mizar, the first binary star discovered from the spectrum.** Even though Mizar appears to be a single star, Pickering's spectrum showed it to be a binary star. You will need to refer to the spectrum shown in class on Oct. 25th. The speed of light is 3×10^5 km/s.

    a. (2 pts.) Look at the drawing of the orbit of the binary star. Be certain to note the location of the earth. Why is there only a single spectral line on 1 and 23 October and two spectral lines on other days?

    b. (2 pts.) Why is the Hβ line of hydrogen not at its laboratory wavelength even on 1 October?

    c. (1 pt.) Find the speed of the center of the binary star system.

    d. (1 pt.) Find the orbital speed of one of the stars.

    e. (0 pts.) What are the big ideas needed to answer this question? (You may want to do this part first.)

2. **Discovery of the first quasar**. In 1962, Maarten Schmidt observed the spectrum of an object that emitted radio waves and visually looked like a star. Since stars do not emit radio waves, this was a very unusual object. He observed the part of the spectrum from 4860 Å to 6030 Å. He found spectral lines at 5571 Å and 4974 Å. You are going to figure out the redshift.

    a. Hint: the same factor $\lambda_{\rm obs}/\lambda_{\rm lab}$ applies to every spectral line. (2 pts.) Explain why.

    b. (3 pts.) *Assume* OII (ionized oxygen with one electron removed) accounts for the line at 4974 Å. What then is the redshift?

    c. (1 pt.) Assume the redshift in part (a) is correct. What is the wavelength at which the line Hε appears in the spectrum of the object?

    d. (2 pts.) Why is the identification of the line at 4974 Å as OII incorrect?

    e. (4 pts.) Now you know the line at 4974 Å is not due to OII. Identify (determine the element and the particular spectral line of that element) these two lines and determine the redshift of this object. Note: Not all of the lines in the table are present in all astronomical objects. However, a line in the hydrogen series cannot occur by itself.

    f. (0 pts.) What are the big ideas needed to answer this question? (You may want to do this part first.)

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.

Line	*Wavelength*	*Line*	*Wavelength*
Hα	6562 Å	OII	3727 Å
Hβ	4861 Å	OIII	5007 Å
Hγ	4340 Å		
Hδ	4101 Å		
Hε	3970 Å		

3. The present distance to Hoag's Object is 300 Mpc, and its speed is 18,000 km/s. For Hubble's constant, use the value 60 km/s/Mpc (equal to 0.061/Byr). A Mpc is 3.1×10^{19} km. A billion years is 3×10^{16} s.
    a. (3 pts.) A billion years ago, Hoag's Object was moving away from us at about the same speed. What is the reason for that?
    b. (3 pts.) How far from us was Hoag's Object at that time?
    c. (1 pts.) What was the value of Hubble's constant at that time? Is Hubble's constant a constant (one that does not change with time)?
    d. (0 pts.) What is the big idea needed to answer this question? (You may want to do this part first.)