D(istance) = d(iameter) / Φ, so for yours, D = 0.03 Mpc/ ___radians. Divide for each galaxy.

a. $D = \frac{0.03\ Mpc}{5.21\times10^{-4}} = 57.6\ Mpc$

7. On graph paper plot the recessional velocity (km/s) on the vertical axis and distance (Mpc) on the horizontal axis. Draw a best line through the 5 points and the origin. (Why should it go through the origin?)

8a. The slope of the line you drew is your value for Hubble's constant.
8b. An accepted value for H is about 75 km/sec/Mpc. How does your compare to this?

For the rest of the problems use this accepted value for H.

9. For a simple cosmological model, the "radius" of universe is calculated from D = v/H, where v is the velocity of light, c, in km/s. Calculate the size of the universe.

   D = 4×10^{3} Mpc

   Convert Mega parsecs into light years by multiplying by 3.26×10^6 LY/Mpc.

   $D = \frac{3\times10^5\ km/s}{75\ km/s/Mpc} \cdot \frac{3.26\times10^6\ LY}{Mpc} = \boxed{1.3\times10^{10}\ LY}$

10. So, since Light Years is the distance light travels in a year, the number of light years is the age of the universe in years.

    Age of universe = 13 billion years.

Questions:

11. For what value of the red shift would v_r equal c?
    (When v = c, we have to use the relativistic form:

    $\frac{v_r}{c} = 1 = \frac{\Delta\lambda}{\lambda}$, so $\Delta\lambda = 395\ nm$

    See #13

12. A new galaxy is discovered in which the H and K lines of calcium are shifted by 43.0 nm.
    12a. What is your estimate of the distance? $v = c\frac{\Delta\lambda}{\lambda} = 3\times10^5\ km/s \cdot \frac{43\ nm}{395.1\ nm} = 3.26\times10^4\ km/s$
    12b. Upon what assumptions is this based? $D = \frac{v}{H} = \frac{3.26\times10^4\ km/s}{75\ km/s/Mpc} = \boxed{4.3\ Mpc}$
    $v < c$, $H = 75$, etc.

13a. For a certain quasar, a line with a lab wavelength of 155 nm is measured to be 310 nm. Find the velocity of recession for that quasar using the Doppler equation.
b. Is this a reasonable value? If not, use the relativistic Doppler formula.
c. Show that this reduces to the usual Doppler equation, when v <<c.

a. $v = \frac{c\Delta\lambda}{\lambda} = 3\times10^5\ km/s \times \frac{155\ nm}{155\ nm} = 3.0\times10^5\ km/s = c$!!   b. No.   c. $v_r = \frac{(1+\frac{\Delta\lambda}{\lambda})^2 - 1}{(1+\frac{\Delta\lambda}{\lambda})^2 + 1} \times c \rightarrow \sim \frac{(1+2)^2-1}{(1+2)^2+1} \cdot c \rightarrow c$

Questions to consider:

1. What effect has the progressive revision of H from Hubble's original value to the present estimate had on our conception of the time and distance scales of the universe?

2. Is Hubble's constant really constant? What would happen if it increases or decreases with distance?

3. What happens to galaxies whose distance is equal to the "radius" of the universe?

4. Is the simple Doppler formula that was used valid for the velocities obtained?

5. Is our assumption of inverse proportionality between size and distance valid in a non-Euclidean universe?