

Homework # 5

Name _____

DUE: November 4 (at the start of class)

NOTE: This homework is worth 30 points!

Your homework grade depends not only upon your getting the correct answer but also grammar, spelling and punctuation, particularly in questions that require explanations. Obviously numerical answers to problems do not need to be written in complete sentences. You will also be graded on the use of significant figures, proper units of measure and proper scientific notation. Partial credit may be given for showing your work even if your result is incorrect. You may work with others in determining the answers to the questions, but what you write should be in your own words – any homework assignments that look too similar to that of other students will receive no credit. Unless otherwise noted, all questions are worth 1 point.

1. (10 points) At the course website there is a link for *Cepheid Light Curve*. Follow this link and you'll come across a program that displays the light curves/variations of Cepheids over time. The program randomly displays data, so you'll want to follow the directions carefully. You'll see data for the first star displayed as a series of magnitude values over a span of days. To see the scale of the days and magnitudes, press the "Grid On/Off" button. You can press the "Connect" button to connect the data points with line segments. Since real data has inherent errors/inaccuracies, the data points are not precise, so the line may look a bit bumpy. You can also use the sliding scale to change the range of dates, which may help the data look better. You should be able to view at least two full cycles of light variation (two peaks and two valleys).

When you click anywhere on the light curve plot, you can obtain values for the date at that location and the magnitude. You need to determine the pulsation period and the average magnitude for 10 Cepheids. The pulsation period would be the time between successive peaks, or successive valleys, basically the time for one entire cycle. The average magnitude can be determined several ways. You could use the average of the maximum and the minimum magnitudes, or estimate with your eye where you think the average is located. Since these are the observed magnitudes, they are *apparent magnitudes*. Once you have value for a star's pulsation period and average magnitude, place them in the table provided. Pressing the "Get New Data" button gives you values for a different star. You'll want a range of values for the stars – if they all have the same period, that's no good. Values can range from 10-50 days.

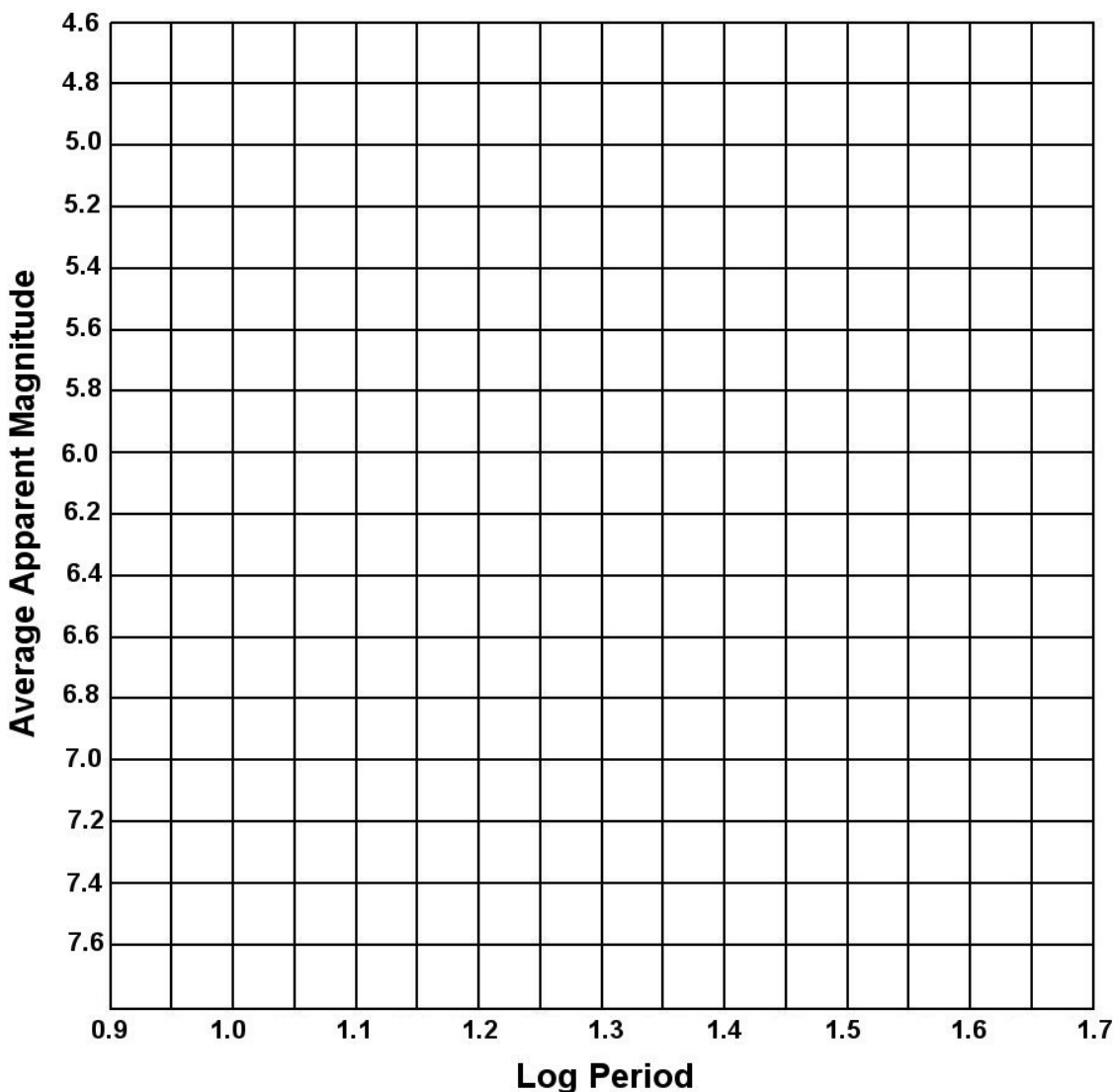
In order to use the data you'll have to take the Log value of the period. There is a button that does this on your calculator. A Log function basically determines what power of 10 is need to create the number. For example, $\text{Log } 10 = 1$, since 10 to the power of 1 equals 10. $\text{Log } 100 = 2$, since 10 to the power of 2 equals 100. And of course the powers can be fractions, such as $\text{Log } 37 = 1.57$ since 10 to the power of 1.57 equals 37. The Log function is very commonly used in astronomy since the numbers can be very extreme and in some cases the Log values behave better than the normal values. Place the Log values for the period in the table as well.

Now you get to really use Cepheids as astronomers use them – to create a Period-Luminosity relation. Using the values for Log Period and the average apparent magnitude, graph the values on the graph paper provided. The data should lie along a fairly straight line on the graph. **Draw the best straight line through the data**, which may or may not go through the points precisely.

If you would rather use a program like Excel to make the graph, that's fine, but be sure to attach it with your homework.

Cepheid	Period (days)	Log Period	Average Apparent Magnitude
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

a. The Cepheids that you are looking at are all located in a distant cluster. In order to determine the distance to the cluster, you'll need to determine the average apparent magnitude for a Cepheid which has value of Log period = 1.4, we'll use this period as a benchmark. Use the line that you drew on your graph to determine the average apparent magnitude for a Log period = 1.4 Cepheid. What value did you obtain from your graph?



b. (2 points) The average *absolute* magnitude for a Cepheid with a value of $\text{Log } P = 1.4$ should be -5.06 . Obviously the Cepheids that you are looking at are much further away, but you can determine the distance by combining the average absolute magnitude (-5.06) and the average apparent magnitude (your answer from part “b”) in the distance-magnitude formula –

$$d(\text{pc}) = 10^{\frac{m-M+5}{5}}$$
 where m = average apparent magnitude, M = average absolute magnitude and d = distance in parsecs. Note that the formula is 10 to the *power* of $(m-M+5)/5$, so determine that first and then take 10 to that power. What is the distance to the cluster?

2. (10 points) **Galaxy Classification.** At the website there are links to images of 20 galaxies. Follow these links and look at the galaxies. Determine their type. Your options are Spiral, Barred Spiral, Elliptical and Irregular. Put only one type down for each galaxy.

Galaxy 1

Galaxy 2

Galaxy 3

Galaxy 4

Galaxy 5

Galaxy 6

Galaxy 7

Galaxy 8

Galaxy 9

Galaxy 10

Galaxy 11

Galaxy 12

Galaxy 13

Galaxy 14

Galaxy 15

Galaxy 16

Galaxy 17

Galaxy 18

Galaxy 19

Galaxy 20

3. (4 points) If an astronomer finds a Main Sequence star with very few heavy elements in it (elements other than hydrogen and helium), she knows that star must have formed a very long time ago (many billions of years ago).

a. How does she come to this conclusion?

b. What sort of mass must this star have, high or low?

c. (2 points total) How did you use to come up with the answer for part “b” – what information did you use to come to that conclusion?

4 (6 points). **Quasars!** These are amongst the most distant objects in the Universe. We believe that is the case because they have very high redshifts and Hubble’s law implies that very high redshifts corresponds to very great distances. But just how high are the redshifts? To find out, you need to go to the course website and follow the *Quasar* link to a program that shows you some quasars and their spectra. An image of the quasar is shown, along with its apparent magnitude. At the bottom, the spectrum of the quasar is slowly being produced. Since quasars are so far away, it takes time for their spectra to fully form. When it does you’ll see it is an emission spectra with some peaks in it. We’ll be interested in only the largest (tallest) peak, so make sure you give the spectrum enough time to completely develop so the largest peak is seen.

If you click on the buttons near the quasar names, you’ll change the image of the quasar and you’ll have to start up the spectrum reading (by clicking on the “Start” button). If you click on the spectra, you’ll get the wavelength of the location you click on. You’ll want to find the wavelength of the largest peak in the spectrum. This feature is supposed to appear at wavelength of 1215 Å, but as you can see it is very far from its normal location – or put another way, the spectrum is very redshifted.

Using the program determine the wavelength for the largest feature in each quasar’s spectrum and the apparent magnitude for each quasar and fill that in the table below.

Quasar	Magnitude	Wavelength (λ)	Z	Velocity (V) km/s
QSO 0				
QSO 1				
QSO 2				
QSO 3				

To determine the value of the redshift, use the relation

$$Z = \frac{\lambda - 1215}{1215}$$

Since these quasars are traveling at good fractions of the speed of light, you'll need to use the relativistic redshift formula to determine their velocities. The formula is in your notes, but if you don't have them handy, it's here as well.

$$V = 300,000 \left[\frac{(Z + 1)^2 - 1}{(Z + 1)^2 + 1} \right] km / s$$

Not the simplest formula, but it gets the job done. Using this formula, determine the velocity for each quasar and fill that in the table above. And then answer these questions.

a. How do the magnitudes correlate with the velocity values?

b. Why does this correlation exist?

c. (2 points) At the course website is a cosmology calculator that you can input different values of redshift (z) in and determine some rather interesting things. Use the largest value of z for your quasars and enter that into the calculator. What was the Universe like when the light left that distant quasar?