Homework

1. Start with the formula for the graviational red shift:

$$f_{\text{obs-top}} = \left(1 - \frac{gh}{c^2}\right) f_{emit-bot}\,.$$

   Thus two clocks, one in orbit at a height of $20,000\,\text{km}$ and one on the surface of the earth, which were synchronized at the beginning of the day, will not be synchronized at the end of the day. Estimate how far off the two clocks will be off after one day:

   - Estimate

$$\Delta t_{\text{earth}} - \Delta t_{\text{satellite}} \tag{1}$$

     where $\Delta t_{\text{earth}} = 1\,\text{day}$. Hint: the approximate formulas for $gh/c^2 \ll 1$ may be useful

$$\frac{1}{1 - gh/c^2} \simeq 1 + gh/c^2 \tag{2}$$

2. Describe what the harvard-tower (Pound-Rebka) experiment measured and how it measured whatever it measured.

3. What are the Cepheid Variables and why were they historically important in determining the overall shape of the galaxy. Who determined this shape and how did he do it.

4. M101 (the pinwheel galaxy) is an important galaxy in the distance ladder, since it is relatively close and can be used to calibrate the Type Ia supernova using Cepheid Variables.

   (a) Go to http://www.atlasoftheuniverse.com and locate M101. (Hint how far can we pick out Cepheid variables – see lecture.)

   (b) Estimate its red-shift, z using your findings on this web-site and the Hubble formula, $v \simeq H_o d$ with $H_o \simeq 70\,\text{km/s/Megapc}$.

   (c) A high-school astronomy buff, tells you that the luminosity of a rare Cepheid found at these distances is 2000 times that of the sun. After observing that this star grows brighter and fainter with over a time of 50 days, you reply that that high-shcool freind must be mistaken. Explain.