Homework 10 Solutions

1. The diameter of the Earth is 7926 miles at its equator. The highest point on Earth (Mt. Everest) is 5.5 miles above sea level; the lowest point (Mariana Trench in the Pacific Ocean) is 6.8 miles below sea level. Hence, the "roughness" of the Earth's surface is 5.5+6.8 = 12.3 miles. What is the ratio of the roughness of the Earth's surface to the Earth's diameter? Express this ratio as a single number in scientific notation.

Take a ratio of the earth's roughness to its diameter: total roughness/diameter. This gives you a measurement of how smooth it is (how big is the biggest bump as a fraction of the total size?). In this case, note that both the roughness of 12.3 mi and the diameter of 7926 mi have the same units. The fraction is therefore quite simple since the units cancel: 12.3/7926 = 1.55×10^{-3}, or .15%

2. A basketball has a diameter of about 25 centimeters (cm). The bumps on a basketball's surface are about 1 millimeter (mm) high. What is the ratio of the roughness of the basketball to the diameter of the basketball? Now, express this ratio as a single number in scientific notation. Based on your answers to questions #1 and 2, would you characterize the Earth as lumpy or smooth in comparison to a basketball? Justify your answer in ***one or two*** sentences by discussing the numbers in the first two questions.

This is very similar to the last problem except that you need to first make the units in the top and bottom of your ratio the same (in order to compare "apples to apples" – your answer to #5 is unitless, so this one needs to be too). You can either convert 25 centimeters to 250mm (25cm x 10mm/1cm = 250 cm), or you can convert 1 mm to 0.1cm (1mm x 1cm/10mm = 0.1mm). Roughness = 1mm/250mm or 0.1cm/25cm. Both are equal to
4×10^{-3}, or .4%

3. Now, compare your answers to questions 1 and 2. You could even take a ratio here! The "roughness of the basketball" as a ratio to the "roughness of the Earth" is 4/1.55. The basketball is 2.6 times rougher than the Earth! In other words, if you were to shrink the Earth down to the size of a basketball and run your hand over its surface, it would feel smoother than a basketball!

4. The distance between the Sun and Earth is 1.5×10^8 km.
The diameter of the Earth is 1.3×10^4 km.

(a) If you could line up a series of Earths side-by-side, how many Earths would fit between the Sun and Earth? Your answer may be expressed as a round power in a single power of ten, such as 10^3.
Divide the total distance between them by the size of one Earth. 1.5×10^8 km/ 1.3×10^4 km is another unitless ratio. You will get that 11,528 Earths fit between the Earth and the Sun. But you're not done! Now, round this to the nearest round power of 10, which is 10,000 or 10^4.

(b) Explain why you think the distance between Earth-Sun seems either crowded or empty by ***discussing*** your answer to part (A). Use only one or two sentences. Be sure you think carefully about the meaning of the word "crowded."

Think about what "crowded" means. Are two planets in a place like the solar system likely to bump into one another? No! The number that you just calculated means that you could fit 10,000+ Earths between the Earth and the Sun, but of course those Earths aren't actually *there! So the solar system is mostly empty space!*

4. The distance between the Sun and the nearest star (Proxima Centauri) is 1.3 parsecs. Recall that there are 3.26 light years in 1 parsec.

(a) It takes light 4.64 seconds to cross the diameter of the sun. How far is this in light years?

Yes the measurement I gave you here is a little funny in that it's a time rather than a distance. There are a couple of ways to approach this. The simplest method and the one that doesn't require you to recall any numbers other than what you're given in the problem (and a couple of everyday time conversions, in fairness) is to consider that light always travels the same speed, so by telling you how long it takes light to travel this distance, you are really being given the distance itself ***in light seconds****. You simply convert this to years using a standard set of conversions – seconds to minutes to hours to days to years. You should find that the distance is*

$$\frac{4.64 light \sec}{1}\times\frac{1hr}{3600\sec}\times\frac{1day}{24hr}\times\frac{1yr}{365day}=1.4\times10^{-7}\,lightyears$$

You may also have recalled the SPEED that light travels and, since I gave you the TIME it takes to travel a distance equal to the diameter of the sun, you could also have used distance = speed x time to calculate the distance. Note that this is ***more work than was necessary*** *– one of the advantages to pondering a problem and considering the most direct route to a solution before jumping into it.*

(c) How many Suns would fit side-by-side between the Sun and Proxima Centauri?

You can either convert the distance to Proxima Centauri into light years to match your answer to (a) or vice versa. Then, simply take a ratio of one to the other as you did in #3. You should get 3.02×10^7, or about 30 million!

5. The distance between our galaxy (the "Milky Way") and the next nearest large galaxy (the Andromeda galaxy or M31) is about two million light-years. The **radius** of the Milky Way is about 50,000 light-years.

(a) How many Milky Ways would fit side-by-side between these two galaxies? Express your answer both in scientific notation and also as the nearest whole power of ten.

Be careful to note that you're given the radius in the MilkyWway, but like the last problem, you need the diameter. You want to know how many Milky Ways fit between the Milky Way and Andromeda, not how many "half Milky Ways" would fit. This gives you a diameter of 50,000lyr x 2 = 100,000lyr for the diameter of the Milky Way. Now you can again take a simple ratio of 2,000,000lyr/100,000lyr or, more appropriately, 2×10^6 lyr/ 1×10^5 lyr, which is equal to 20. Only 20 Milky Ways fit between the Milky Way and Andromeda! To the nearest whole power of ten, this is 1×10^1, or 10!

(b) Compare your answers to questions 3, 4b and 5a. Which situation do you think seems most crowded, the Solar System, the space between stars, or the space between galaxies? ***Explain your reasoning*** using complete sentences.

20 is way less than 11,000 or 30,000,000! Galaxies are MUCH more likely to bump into each other than planets or stars, since their sizes are very large as a fraction of the space between them (just 1/20, which seems like a small number, but is very large compared to 1/11,000 or 1/30,000,000!) The universe is comparatively "crowded" on a galaxy scale!