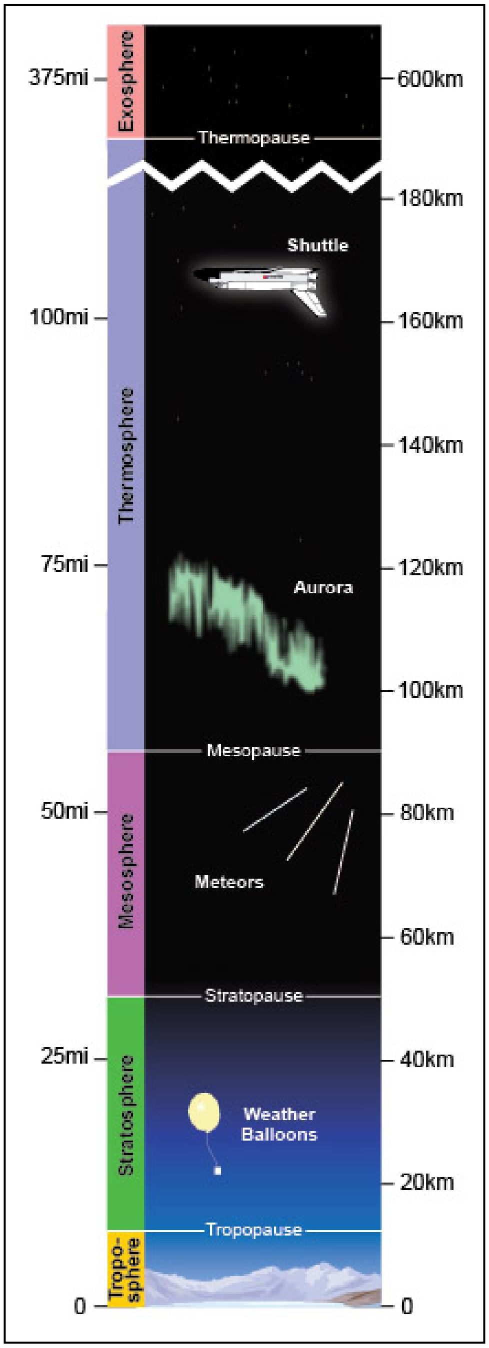

NASA's Van Allen Probes spacecraft will be exploring a region of space near Earth where the atmosphere of Earth is almost non-existent, but it can still be measured. Scientists use density as a way to show just how much gas there is in a cubic meter of space if you were to collect all of the gas in such a box.

On Earth we often talk about a rock being dense, and measure density in kilograms per cubic meter. For most rocks, their densities are 3000 kg/m^3, so if you had a pick-up truck that could hold 1 cubic meter of rock, it would hold 3000 kilograms of mass or 3 metric tons!

Gas is so dilute that, instead of writing density as kilograms/m^3 we use atoms (or molecules) per cubic meter. This tells us how many particles of gas are in a cubic meter. Because the number of particles is so large, we sometimes have to use scientific notation to write them!

Problem 1 – At sea level, the average density of air molecules (oxygen and nitrogen) is 2.5×10^{25} molecules/m^3. Write this number in: A) decimal form, B) by using 'million', 'billion', 'trillion' etc.

Problem 2 – Imagine a piece of paper 1000 kilometers on a side. How many dots would you have to place in each square that is 1 cm on a side in order to fill up the page with this many dots?

Problem 3 – The mesosphere is one of the highest levels of the atmosphere and at 70 km has a density of 0.00001 kg/m^3. This is 100,000 times lower than the density of the atmosphere at sea level. How many dots would you have in each cell of the paper you used in Problem 2?

Problem 4 - In the Van Allen belts, which is located above the exosphere, the density of particles is about 900 atoms/m^3. If you used the same 1000 km wide piece of paper, how far apart would the atoms of the Van Allen belt be on this scale?

Problem 1 – At sea level, the average density of air molecules (oxygen and nitrogen) is 2.5×10^{25} molecules/m^3. Write this number in: A) decimal form, B) by using 'million', 'billion', 'trillion' etc.

Answer: A) 25,000,000,000,000,000,000,000,000 molecules/m^3.
B) 250 trillion trillion molecules/m^3.

Problem 2 – Imagine a piece of paper 1000 kilometer on a side. How many dots would you have to place in each square that is 1 cm on a side in order to fill up the page with this many dots?

Answer: First we have to find out how many 1 cm^2 squares there are in a 1000 km x 1000 km piece of paper. Since 1 km = 1000 meters and 1 meter = 100 cm, each side of the paper measures 100,000,000 cm, (10^8) so the area of the paper is $(100,000,000)^2 = 10^{16}$ = 10 thousand trillion cm^2. There are 10 thousand trillion squares on the page, so the number of dots we need to put in each square is
250 trillion trillion / 10 thousand trillion = $2.5 \times 10^{25}/10^{16}$ = 2.5×10^9 or **2,500,000,000 dots!**

Problem 3 – The mesosphere is one of the highest levels of the atmosphere and at 70 km has a density of 0.00001 kg/m^3. This is 100,000 times lower than the density of the atmosphere at sea level. How many dots would you have in each cell of the paper you used in Problem 2?

Answer: If the density is 100,000 lower, then you only need a **total** of $2.5 \times 10^{25}/10^5 = 2.5 \times 10^{20}$ dots over the entire sheet. This means that each 1 cm^2 square will only need 100,000 times fewer dots or $2.5 \times 10^9/10^5 = 2.5 \times 10^4$ = **25,000 dots**.

Problem 4 - In the Van Allen belts, which is located above the exosphere, the density of particles is about 900 atoms/m^3. If you used the same 1000 km wide piece of paper, how far apart would the atoms of the Van Allen belt be on this scale?

Answer: You want 900 atoms scattered across a 1000 km x 1000 km piece of paper. Because 30x30 =900, that means that along each side of the paper we would mark off 30 atoms, and complete a grid with this spacing covering the 1000km x 1000km page to mark 900 points. Since 1000 km/30 = 33 1/3 kilometers, the atoms of the Van Allen belts on this scale would be about **33 kilometers apart!**