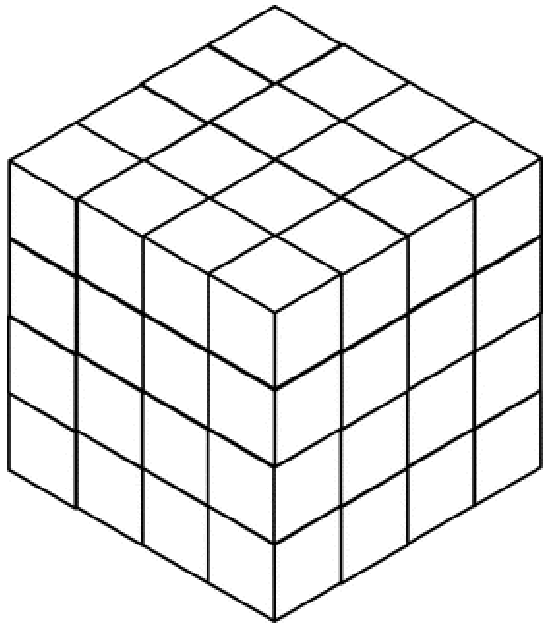
Exploring Gas Density in Space



Earth's atmosphere does not have a hard edge that says 'this is where space starts'. Instead, the density of the atmosphere gets smaller and smaller…but it never quite becomes zero!

Scientists measure gas density in space in terms of the number pf particles that you would find in any cubic meter of space. This is called the **Number Density, n,** and is measured in particles/m^3. Near the Earth, the gas densities are so large that we have to use scientific notation to write them. For instance, at Earth's surface, the number density of air is $n = 2.5 \times 10^{25}$ molecules/m^3. In the mesosphere at 70 km altitude, it is $n = 2.5 \times 10^{20}$ molecules/m^3.

Imagine the each particle sits at the center of its own cube. The number of these cubes, N, in <u>one cubic meter</u> is just the gas number density: **N = n.** In the figure above n = 64 if the length of each cube edge is 1 meter.

Problem 1 - Suppose you had 64 cubes arranged in a cube with a side length of one meter. How far apart would the centers of each cube be?

Problem 2 – Suppose that the large cube had an edge length of 1 meter and it contained 1 million identical cubes. What would the distance between the cube centers be?

Problem 3 – In the Van Allen belts, the average number density is about 900 particles/m^3. What is the average distance between the atoms in the Van Allen belts?

Problem 4 – In the mesosphere, the average number density is about 2.5×10^{20} particles/m^3. What is the average distance between the atoms in the mesosphere in microns, where 1 micron = 10^{-6} meters?

Problem 1 - Suppose you had 64 cubes arranged in a cube with a side length of one meter. How far apart would the centers of each cube be?

Answer: 64 cubes arranged in a cube means that you have 4 cubes along each side so that 4 x 4 x 4 = 64 cubes total. If the length of each side is 1 meter, then the center to center distance for the cubes is just 1 meter/4 = **25 centimeters**.

Problem 2 – Suppose that the large cube had an edge length of 1 meter and it contained 1 million identical cubes. What would the distance between the cube centers be?

Answer: 1 million = 100 x 100 x 100 so there are 100 cubes along each edge, and since each edge measures 1 meter, the separation between the cubes would be 1 meter/100 = 1 centimeter.

Problem 3 – In the Van Allen belts, the average number density is about 1000 particles/m^3. What is the average distance between the atoms in the Van Allen belts?

Answer: The number of cubes along each side is (1000)1/3 = 10 so the distance is d = 1 meter/10 = **10 centimeters.**

Problem 4 – In the mesosphere, the average number density is about 2.5×10^{20} particles/m^3. What is the average distance between the atoms in the mesosphere in microns, where 1 micron = 10^{-6} meters?

Answer: The number of cubes along each 1-meter side is $(2.5 \times 1020)^{1/3} = 6.3 \times 10^6$. The average separation between atoms is then 1 meter/$6.3 \times 10^6 = 1.6 \times 10^{-7}$ meters. Since 1 micron equals 10^{-6} meters so the atoms are separated by **0.16 microns**.

Note: The general formula for particle separation is

$$D = \frac{1 \text{ meter}}{n^{1/3}}$$

where n is the number density in particles/m^3