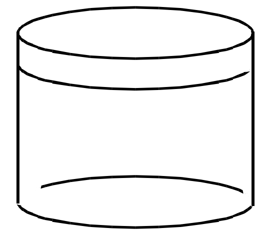
PhyzGuide: Scattering

or "Why the sky is blue"

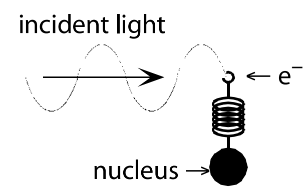
Why is the sky blue? The earth's atmosphere is made of nitrogen (N_2 molecules—78%) and oxygen (O_2 molecules—21%); nitrogen and oxygen are colorless gases. The minor constituents of the atmosphere—argon (Ar), carbon dioxide (CO_2), water vapor (H_2O), neon (Ne), helium (He), and methane (CH_4)—are likewise without hue. Air itself is not blue! A bottled sample of atmosphere is—as they say in chemistry—colorless, odorless, and utterly tasteless.* We might expect the sky to be black, like it is on a sunny "day" on the moon. But when we look at the sky on a clear day, it *is* blue, not black.



A JAR OF AIR.
Air is colorless, the sky is made of air, so the sky should be... ...BLUE?

How come?

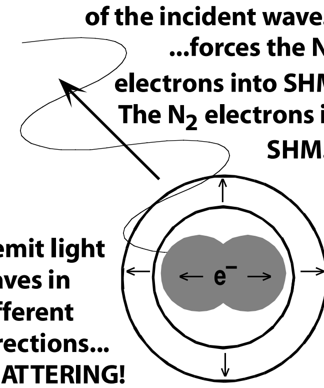
The simple answer is "scattering." But that's just a word, and should hardly satisfy your need for an explanation. What is scattering, and why does it make the sky appear blue?



The electron is anchored to the nucleus and acts like a mass on a spring: it's a harmonic oscillator. If the electric field of an incident wave oscillates at just the right frequency, the electron is driven into resonance

The sun radiates electromagnetic waves of myriad wavelengths. Among that multitude, waves with $\lambda \approx 10^{-7}$ m can force electrons in N_2 and O_2 molecules into resonance.** This is because electrons in N_2 and O_2 have a "natural" or resonant frequency of about 10^{15} Hz. Only light with a wavelength of $\sim10^{-7}$ m ($f \approx 10^{15}$ Hz) will cause pure resonance. A resonating electron is an oscillating electron, and an oscillating electron does what? Yes—it emits an electromagnetic wave! The electron's frequency of oscillation is the frequency at which it is driven by the waves incident upon it ($\sim10^{15}$ Hz). The electron therefore emits electromagnetic waves at $f \approx 10^{15}$ Hz and thus $\lambda \approx 10^{-7}$ m.

Light of $\lambda \approx 10^{-7}$ m incident on atmospheric molecules drives electrons in those molecules into resonant oscillation. The oscillation of those electrons produces light of $\lambda \approx 10^{-7}$ m. That light is aimed radially outward from the electron. *This* is what we call scattering (*Rayleigh scattering* to be more specific).



*unless you live in Los Angeles ...or Sacramento on a bad day

**Resonance is the forced vibration of an oscillator at its natural frequency.

This would be a dandy explanation if it weren't for one minor problem: The resonant frequency of N_2 and O_2 molecules corresponds to UV light, so the sky should be filled with scattered UV light (a suicidal sunbather's paradise). But most UV light from the sun is absorbed by ozone (O_3) in the upper atmosphere. Violet light can force N_2 and O_2 molecules into a close approximation of resonance, resulting in scattered violet light. However, our eyes are not very sensitive to violet light. So the sky does not appear violet. Blue is the next closest wave to induce a "psuedo-resonance" among atmospheric molecules. Although blue light is scattered less than violet, our eyes are more sensitive to blue light. So the sky *does* appear blue. Longer wavelength light caused by lower frequency oscillations (i.e. green, yellow, orange, and red) are scattered less depending on how much they differ with UV. Red, for instance, plows right through the atmosphere and suffers very little scattering.