Fermi Questions

Introduction
Enrico Fermi (1901-1954) was a very unusual physicist in that he was both an excellent experimentalist and an outstanding theoretician. In 1938 he won a Nobel Prize for his work in elementary particle physics, and four years later he produced the first nuclear chain reaction, ushering in the nuclear age.

Fermi was very good at finding simple solutions to difficult problems. He displayed this skill at the time of the first explosion of a nuclear weapon, north of Alamogordo, in 1945. Before the bomb detonated, Fermi tore a sheet of notebook paper into small bits. Just as the shock wave of the explosion approached, he released the bits above his head. They fluttered down, landing about two and a half yards behind him, away from the growing mushroom cloud. Based on this, he quickly calculated that the bomb's energy had been equivalent to that produced by ten thousand tons of TNT.

Later analysis of data collected by sophisticated instruments at the site confirmed his estimate. Although people have suggested possible methods for making this prediction, no one knows for sure just how Fermi did it. To try to pass this skill on to his students, Fermi developed a type of question, or problem, that has been associated with his name, "Fermi Questions." This type of problem has a characteristic nature. Upon hearing it, one doesn't have even the remotest notion of what the answer might be, and one feels that too little information exists to find a solution. Yet when the problem is broken down into subproblems, each answerable, one can make an estimate that comes remarkably close to the exact solution.

For example, suppose one is asked to determine the circumference of the earth without looking it up. If one knows that:

- the distance between New York and Los Angeles is about three thousand miles, and that
- the time distance between the two coasts is about three hours
- then one can reason that
- three hours corresponds to one-eighth of a day, and that
- a day is the time taken for one complete revolution of the earth

Then one can then estimate that the circumference of the earth is about eight times the distance between New York and Los Angeles, or about twenty-four thousand
miles (which is very close to the exact answer. At the equator the earth’s circumference is 24,902 miles.)

Sometimes the questions seem whimsical. For example, how many piano tuners are there in New Mexico / El Paso? There is no standard solution, but anyone can make assumptions that quickly lead to an approximate answer. For example, one can take the total population, assume that an average family consists of four people, and that one-fifth of all families own pianos. If each piano is tuned every five years, there are so many tunings a year. If each tuner can service four pianos a day, 250 days a year, this gives 1,000 tunings a year. From this one can estimate the number of piano tuners. (To check one can look up "piano tuners" in the yellow pages.) Someone might dispute any one of the assumptions made, but in any string of calculations it is unlikely that the estimates made will all be too large or too small. Chances are that the over-estimates and the under-estimates will somewhat compensate in most cases.

Here are some additional "Fermi Questions" you can practice on:

- How many iron atoms are in the head of a pin?
- How many kilograms of one-dollar bills would be needed to equal the national debt?
- How many people die every day in the whole world?
- If you drive from Las Cruces to Albuquerque, how many meters do you drive with your eyes closed due to blinking?
- What is the sum of the first two million positive integers?

Other Fermi questions have been compiled on the web at:

http://www.physics.umd.edu/perg/fermi/fermi.htm

Contest Rules:
For this event you will be asked to answer questions of this type. Remember, the answers themselves will not be as important as the reasoning you used to get them, so it is important to explain in some detail how you arrived at your answers.