

# 1 What Is a Fermi Question?

A Fermi question is an estimation problem named after Enrico Fermi, a physicist known for his ability to make good approximate calculations with little to no actual data. How is this possible? Enrico Fermi made justified guesses about the quantities he needed for his calculations. This is the same technique used to solve any Fermi question. (Keep in mind that this estimation will almost never be the exact answer, but it should be reasonably close.)

Here is an example of a simple Fermi problem: How long does it take Mr. Lomas to grade his students' chapter 1 geometry tests?

First, let's do some quick estimations:

1. How many papers does Mr. Lomas have to grade? In other words, how many students take geometry?
2. How many problems are there on the test?
3. How long does it take to grade each problem?
4. Using the answers to the previous questions, answer the main question.

Now, let's try one that's a little harder. The classic Fermi problem, which is generally attributed to Fermi himself, is "How many piano tuners are there in Chicago?" Let's use the Fermi method to approximate the answer.

First, let's do some quick estimations:

1. How many people live in Chicago?
2. How many households are there in Chicago? (In other words, how many people are in an average household? Use this to find your estimation.)
3. How many households have pianos that are tuned regularly? (In other words, one out of how many households has a regularly-tuned piano? Use this to find your estimation.)
4. How often is each of these pianos tuned?
5. How long does it take a piano tuner to tune 1 piano? (Include travel time in your estimate.)
6. How many hours does each piano tuner work per year? (It may be easier to start your estimate with how many weeks each piano tuner works per year, then how many days per week, then how many hours per day.)
7. Using the above estimations, how many piano tunings occur in 1 year in Chicago?
8. Using the above estimations, how many piano tunings does each piano tuner perform in 1 year?
9. Using the above calculations, how many piano tuners are there in Chicago?

Share your answer with other people. How similar are your answers? What causes these variations? The actual number of piano tuners in Chicago is around 290. How close is your estimate? (It's normal for your answer to be a little off.)

## 2 Additional Food for Thought

Now that you've seen how the Fermi method can be applied, try your hand at these problems. Feel free to collaborate with other people at the meeting!

1. How many Skittles would it take to reach the top of the Empire State Building? (Imagine stacking them on their "front faces" straight up the side of the skyscraper.)
2. How long would it take Mr. Ogle, a math teacher at Amador Valley HS, to grade four classes' worth of Honors Algebra II and Trigonometry tests?

(Ask us for the actual answer (this will be a rather generous estimation). How close was your estimate? Why could your estimate be slightly off from the actual value?)

3. How long would it take a bowling ball to fall to the bottom of the Mariana Trench? (This is the deepest (currently discovered) part of the ocean.)
4. How many fish live in the Indian Ocean?

5. How many tortilla chips does the average American eat in a lifetime?

6. How many cars are sold monthly in the state of California?

### 3 Extension: The Fermi Paradox

A question that has stumped scientists time and time again is, "Is there life outside of Earth?" You have already seen the usefulness of the Fermi method in solving estimation problems. But can this process also be used to find an answer to this age-old question?

"Where is everybody?" -Enrico Fermi

Physicists Enrico Fermi and Michael H. Hart made the following observations:

1. The Earth is part of the solar system. Billions of solar systems make up a single galaxy, and our galaxy is called the Milky Way. Billions of galaxies like the Milky Way make up the universe.
2. There are billions of stars in the universe that are similar to our Sun.
3. Almost certainly, some of these stars will have Earth-like planets orbiting them. Out of these millions of Earth-like planets, some of these may also develop intelligent life.
4. Some of these civilizations may develop interstellar (between stars) travel (we are currently investigating this technology).
5. Even at the slow pace of our currently envisioned interstellar travel, the galaxy can be completely colonized in a few tens of millions of years.
6. Our solar system is relatively young, so some of the other older solar systems in the Milky Way should already have developed this technology and communicated with us.

According to these assertions, the Earth should already have been colonized, or at least visited. However, we have no evidence of either scenario, or even any confirmed signs of extraterrestrial intelligence. This apparent paradox prompted Fermi's above question: "Where is everybody?"