

## Enrico Fermi

Enrico Fermi (1901-1954) was an Italian physicist who made significant discoveries in nuclear physics and quantum mechanics. In 1938, he received the Nobel Prize in physics for his discovery of nuclear reactions caused by slow neutrons. This mechanism led directly to the development of atomic bombs and nuclear fission reactors. After receiving his Nobel Prize, he emigrated with his family to the United States to escape the fascist regime of Benito Mussolini, where he soon began contributing to the Manhattan Project.

Fermi was famous for being able to make good estimates in situations where very little information was known. When the first nuclear bomb was tested, Fermi was nearby to observe. To get a preliminary estimate of the amount of energy released, he sprinkled small pieces of paper in the air and observed what happened when the shock wave reached them. (Being so close to the bomb on this and many other occasions exposed Fermi to dangerous radiation that led to his death by stomach cancer at the age of 53. Fermi was aware of the danger, but chose to work on this project anyway because he believed that the work was vital in the fight against Fascism.) Fermi often amused his friends and students by inventing and solving whimsical questions such as “How many piano tuners are there in Chicago?”.

A “Fermi Question” asks for a quick estimate of a quantity that seems difficult or impossible to determine precisely. Fermi’s approach to such questions was to use common sense and rough estimates of quantities to piece together a ball-park value.

For example, one way to estimate the number of piano tuners in Chicago is to break the process into steps: estimate the population; estimate the number of households in the population; estimate the fraction of households that have pianos; estimate how often each household has its piano tuned; estimate the time it takes to tune a piano; estimate how many hours a piano tuner would work each week.

In this case, it is possible to check the estimate by looking in the phone book to see how many piano tuners are actually in Chicago.

## Fermi Questions in Everyday Life

Here are a few examples of practical Fermi Questions.

- In business: “How big is the local market for handmade gourmet dog treats?”
- In environmental policy: “By how much would the amount of trash in landfills be reduced if it became illegal to throw away plastic grocery bags?”
- In educational policy: “If the school district reduces the maximum class size to 20 students, how much would it cost to hire the extra teachers?”
- In public health: “A virulent strain of influenza is spreading and everyone in our county needs to be vaccinated by a qualified health care professional. How quickly can this be done?”
- Personal finance: “I am going to work in a fast food restaurant to cover my college tuition, books, and living expenses. Will I need to take out a loan? Will I have enough study time?”
- Event planning: “Our city is organizing a parade with a mile-long route. About 150 organizations have expressed interest in being in the parade. For how much time will the streets need to be closed along the route?”

It is empowering to cultivate your ability to think about these kinds of big picture questions. Thinking this way can enable you to dream big and accomplish your goals. Practicing this skill can equip you to identify opportunities and dangers that are not apparent to most people.

## Fermi Questions Lab

Record your answers to each question on another page. Be sure to write your team name, list the members of your team, and write out the Fermi question you are investigating.

1. Question: State the question and discuss how you will interpret it.
2. Wild Guess: What is your answer without any calculating?
3. Educated Guess: List the pieces of information you will need to answer this Fermi question more precisely. Estimate the value of each quantity in your list. Based on your estimates, what is your solution to the Fermi question? Show all your steps and use words to explain them.
4. Variables and Formulas: Choose variable names for each quantity that you estimated. Write a series of formulas or a procedure that explains how you used the quantities to find the solution. Try to simplify the process into a single formula that answers the Fermi question if possible.
5. Gathering Data: Perform experiments, conduct surveys, make measurements, or search for information that would help you to obtain a more precise estimate. For each quantity, identify the smallest possible value, the largest possible value, and the most likely value (you will probably have to use your best judgement to estimate these values). Then use the formula you found in the previous step to find the smallest likely answer to the Fermi question, the largest likely answer to the Fermi question, and the most likely answer to the Fermi question. Show your work!
6. Conclusions: State your final answers to the question. Explain some possible sources of error in your procedure. List any interesting facts that you learned while seeking the answer to the Fermi question. Finally, describe a further direction that you could pursue if you wanted to extend your investigation into this topic.

## Sample Fermi Questions

1. In Bendix Woods near the old test track, the word STUDEBAKER is spelled out in pine trees so that it is visible from the air (check out the satellite image online). How many pine trees were required?
2. What would it take to fill this room with popcorn?
3. If you prepared a tank with all of the air you need to breathe in one day, how large would it be?
4. How many people in the world are talking on their cell phones at this instant?
5. If all the people of the world were crowded together, how much area would we cover?
6. If everyone in our city donated one day's wages to a good cause, how much money could be raised?
7. How many dump trucks would it take to cart away Mount Everest?
8. How many people would be required to surround this city if they held hands?
9. How large a landfill would our county need to store 100 years of garbage?
10. How many square miles of paved surfaces are there in our city?
11. How much gasoline does a typical automobile use during its lifetime?
12. How many people are airborne over the US at any given moment?
13. How much money could the city of South Bend save this year by shortening the work day of all city employees by one hour?
14. How many port-a-potties should be planned for the next million-man-march?
15. After the gulf war, large areas of desert had to be cleared of mines using special bulldozers with blades strong enough to withstand the explosion of a mine. Estimate how long it would take a single bulldozer to clear a patch of desert that is 10 km square.
16. Estimate the number of blades of grass in a typical lawn in your neighborhood.
17. How many musical notes are played on your favorite radio station in a given year?
18. How many gallons of water move down the Mississippi River in one day?
19. How far does a bumblebee fly each day?
20. If there were no traffic, how quickly could a race car travel from Washington D.C. to Los Angeles?
21. If BP is unable to stop the flow of oil in the Gulf of Mexico, how much oil will escape? How many pounds of greenhouse gases will be released into the atmosphere this year as a result, and how does this compare to the annual greenhouse gas emissions typical for the United States? If you stood in one place along the coastline and siphoned off all the oil that you could reach, how much oil could you gather in a week?
22. How long would your hair be if it never broke or was cut from the time you were born until now?
23. How many dollars worth of pennies would you need to stack to equal your height, the height of the school, the tallest building in the world, Mount Everest, outer space.
24. What is the current population of mosquitos in our county?
25. How much milk is produced in the United States each year?
26. How many pencils would it take to draw a straight line along the entire Prime Meridian of the Earth (assuming that a suitable drawing surface could be placed along the entire route)?
27. If you took the thread from all the uniform shirts of the Notre Dame football team and laid them end-to-end, how many times could you wind it around the football stadium at Notre Dame?
28. If all the pizzas eaten by students in your school last year were laid out next to each other, what area would be covered?
29. How many people attend Art Beat in South Bend each year?
30. How many grains of sand are there on the beaches surrounding Lake Michigan?
31. If you posted an advertisement on a billboard on Lincoln way for one month, how many people would be likely to see it?
32. How many desks occupy 7th grade math classrooms in the state of Indiana?
33. How many plastic flamingos still exist in the United States?
34. Of all classified mentally ill persons, how many are diagnosed with schizophrenia (world wide)?
35. What is the total number of shots taken in one NBA season (including the tournament)?

36. How many yards of thread in a shirt?
37. How many sheets of toilet paper in the school?
38. How many sheets of copy paper in the school?
39. How many ceiling tiles in the room?
40. How many blades of grass in a football field?
41. How many minutes does the average student play video games per day, week, year, 10 years, et cetera?
42. What is the cost of food for the children in the Family Literacy program for one year?
43. What is the cost of transportation for the Family Literacy program for one year?
44. How many screws would it take to put the floor down for the Boston Celtics at the Garden?
45. How many hot dogs are bought at all the Major League Baseball games for one season?
46. How many water droplets make up fog? Stratus clouds? Cumulus clouds? Cumulonimbus clouds?
47. How many hours of sleep will I have in my lifetime?
48. What is the graduation rate of students I have taught over the past 22 years?
49. How many texts does the average 8th grader send per year?
50. How much food waste does the school have in a month?
51. Not counting the hours when you are asleep, how does the amount of time you are in school compare with the amount of time you are out of school?
52. What is the average lifetime of a pencil?
53. How much popcorn is popped at the movie theater on an average Saturday?
54. If you played your favorite song continuously for a whole year, how many times would it play?
55. How many times does your heart beat per day? Per week? Per year?
56. How many marshmallows would it take to cover your desk?
57. How many M&Ms would it take to cover the floor?
58. How many hours of tv will you watch in your lifetime?
59. How many pennies in my jar?
60. How many times would my 22 inch rims go around if I could drive around the equator of the Earth?
61. How many calories does a student burn while switching classes? How does this compare with the number of calories in a school lunch?
62. How many steps would I need to climb to burn as many calories as there are in a bag of potato chips?
63. How many laps would I need to make around our classroom to go a mile?
64. How many laps around our school would burn enough calories to lose a pound?
65. Do you burn more calories using stairs?
66. How many pizza boxes would we need to cover the classroom floor?
67. How many sticky notes would it take to cover the chalkboard? What if we use different size sticky notes?
68. What is the weight of a building?
69. How many sheep would it take for every person in the world to have a wool sweater?
70. What is the average number of bricks used to build a building?
71. How many gum balls would it take to reach from the Earth to the Moon?
72. How many strands of hair do you have on your head?
73. How many snowflakes would it take to completely cover a driveway?