

FERMI PROBLEMS

Estimating rather than guessing

Detailed Explanation: http://www.ph.utexas.edu/~gleeson/httb/section1_3_3_5.html

Not every problem needs a precise solution. An estimate of what to expect may be sufficient. Estimates are important because they provide a frame of reference. Without a frame of reference, there is really no basis for action.

Enrico Fermi was one of the most important research physicists of this century and a great many of the working tools of the modern physicist were invented by him. He was also for many years a professor at the University of Chicago and had a reputation for asking his students seemingly impossible questions. However, he demonstrated that they had the resources to get a reasonable answer, hence these estimates are called Fermi Problems.

Estimations: The point of Fermi problems is in part to show how much use can be made of commonly available knowledge by the person willing to be resourceful, use general knowledge, heuristics and make approximate simple calculations. Each assumption is stated. Therefore, the entire process can be checked if the final answer appears unreasonable.

Note that the assumptions and approximations do not have to be correct. In fact, the result using this method is that the result can be better than the individual assumptions, since, in a multi-step problem, random errors in the approximations may self-cancel.

Guesses: This procedure is contrasted with guessing. The basis for a guess cannot be clearly identified. Thus, there is not a way to gauge the quality of the answer, and thus how much confidence to put on it. Since the guess often has intuitive components, there is not a way to check it.

Advantage: Estimation allows you to bring more information to the situation. More information means better results. It also means less dependence on circumstance. As discussed earlier about confusion and confidence, the first response to a question may be "I have no idea!" Allow that response to form and be released, then go back to analyzing the problem, perhaps using heuristics and approximations, and generate information for yourself.

Fermi's Piano Tuner Problem

The most famous Fermi problem was quite simply stated: How many piano tuners are there in Chicago (home city). Here is the approach laid out on a NASA website:

(NASA: https://www.grc.nasa.gov/WWW/k-12/Numbers/Math/Mathematical_Thinking/fermis_piano_tuner.htm)

1. Now, assume that an average family contains four members so that the number of families in Chicago must be about 750,000.
 2. If one in five families owns a piano, there will be 150,000 pianos in Chicago.
 3. If the average piano tuner
 - a. serviced four pianos every day of the week for five days
 - b. rested on weekends, and
 - c. had a two week vacation during the summer,
1. Then in one year (52 weeks) he would service 1,000 pianos. $150,000 / (4 \times 5 \times 50) = 150$, so that there must be about 150 piano tuners in Chicago.

This method does not guarantee correct results; but it does establish a first estimate which might be off by no more than a factor of 2 or 3--certainly well within a factor of, say, 10. We know, for example, that we should not expect 15 piano tuners, or 1,500 piano tuners.

Guided Example

What is the mass of the earth? Complete this problem using the information below as guidance.

Draw a flow diagram for what is needed:

Earth Composition	Earth is primarily rock
Density of Rock	Heavier than water >1 kg/L, 1 kg/1000cm ³ , 1000kg/m ³ How much heavier? Compare weight of same volume of rock and water Estimate: 2x, 5x, 10x, 100x
Radius of Earth	Knowledge? There are 24 time zones: LA and NY are 3 time zones apart. What is an estimate of their distance
Circumference	General Math
Volume of a Sphere	General Math or estimate form a volume of a cube
Calculation	Complete the calculations and check your answer. Remember, no one has ever weighed the earth, others have used different estimates.

Additional Problems:

How many tennis balls will fit in the classroom?

How many pizzas will be eaten by BHSEC students this school year?

How much of your food goes into doing a day's physical work, and how much just to keeping you alive?

