✖

Estimating

5/5 points earned (100%)

Retake

Course Home

Excellent!

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1 / 1
points

1.
[#141] **How many dentists in Sydney?**

How many dentists are there in Sydney? Here are some relevant data. Sydney's population is about 5 million people. Suppose that, on average, each person spends 2 hours at the dentist every year. (Yes, if you have good teeth it's a lot less than that, but many people spend a lot of time at the dentist.) You need one more datum, but I'll leave you to think of that one.

Enter your answer as an integer (no units) and remember that Sydney's population and the amount of time each person spends at the dentist are given to one significant figure.

10000

Correct Response
Nice work!

The other datum you need is the average number of hours worked per year by dentists. If each dentist works 40* hours per week, for 50 weeks a year, they will be able to work for $40 \times 50 = 2000$ hours per year, and see $2000/2 = 1000$ patients. This means there would have to be roughly $\frac{5{,}000{,}000}{1000} = 5000$ dentists in Sydney to service Sydney's entire population.

I look up the telephone directory and find 6191 dentists: This is rather flattering, because the input data were much rougher than this approximate agreement might suggest.

What has this question got to do with physics? Only that it's a good example of an estimation problem and that physicists are expected to be good at problems like this. You might like to think up one of your own and share it with us in the forums.

* We include a range of values for the answers because yes, they may not work 40 hours per week.

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1 / 1
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2.
[#142] **How many cells are you?**

How many cells in a human? Assume that cells have a typical size of about 10 μm ($1\mu\mathrm{m} = 10^{-6}\ \mathrm{m}$) in all directions. And that we are the same density as water, and are made completely of cells (both exaggerations, of course, but fine for an order of magnitude estimate). (Hints: What is the volume of a human? What is the volume of a cell? How can these quantities be related to give the number of cells in your body?)

When you enter your answer, enter it as a power of 10. For example: "10^32", or "10^5".

Preview

100000000000000

10^14

Correct Response
Excellent! Did you use the method shown here?

$$\#\text{ of cells in a human} = \frac{\text{volume of human}}{\text{volume of cell}} = \frac{\text{mass of human}}{\text{density of water} \times \text{volume of cell}}$$

$$\sim \frac{100\ \mathrm{kg}}{1000\ \mathrm{kg{\cdot}m^{-3}} \times (10^{-5}\ \mathrm{m})^3} = 10^{14}$$

Interesting fact #1: This very rough calculation is about a factor of 2 bigger than a serious scientific calculation: Bianconi et al. (2013) 'An estimation of the number of cells in the human body', Annals of Human Biology, 40, 463–71.

Interesting fact #2: Bacterial cells are much smaller than human cells, so the number of bacteria in our intestines outnumber significantly the number of 'our' cells.

Interesting fact #3: Beyond the scope of this course, I use this calculation whenever I teach entropy, to make clear the very great difference between molecular disorder, which is related to entropy, and macroscopic disorder, which is always negligible in entropy calculations. (Search 'Cellular thermodynamics', if you're really geeky.)
Your answer, 10^14, is equivalent to the instructor's answer 10^14.

1 / 1
points

3.
[#143] **A grain of sand...**

How many atoms in a grain of sand? Make a guess first: Is it more or less than what we found for the number of grains of sand on a beach?

- There are more atoms in a grain of sand than grains of sand on a beach.
- There are more grains of sand on a beach than atoms in a grain of sand.

For this question we accept any answer as correct. You'll see why later.

- There are roughly equal numbers of sand grains on a beach and atoms in a sand grain.

1 / 1
points

4.

[#144] **How many atoms?**

How many atoms in a grain of sand?

This one requires more steps, but let's find an answer. This question is an order-of-magnitude estimate. Approximate as a power of ten.

When you enter your answer, give only the exponent. For example, if you think there are 10^{32} atoms in a grain of sand, write 32.

Before you begin, here's a datum to start you off: 20 grams of sand contains 6×10^{23} atoms*. (For people used to imperial units, a gram is 0.035 ounces and a kilogram is 2.2 pounds mass. But, because this is a science course, you'll need to get used to kilograms and the rest of the metric units.)

What about the density of sand? Is it higher or lower than that of water ($1000\ \mathrm{kg/m^3}$)? How do you know? Is it higher or lower than that of iron ($7860\ \mathrm{kg/m^3}$)? This is an order-of-magnitude problem, so that's close enough! You'll also need to know the size of a grain of sand: now where could you possibly find that out?

* We hope you want to know why. First, in spite of the subtropical coral off the coast, Sydney's beaches are mainly crushed sandstone or quartz, and thus mainly silicon dioxide, $\mathrm{SiO_2}$. In both physics and chemistry, we use a quantity called a mole: a mole is 6.02×10^{23} particles. Silicon has molar mass 28 g/mole and oxygen 16 g/mole, meaning a molecule of $\mathrm{SiO_2}$ has a molar mass of $28 + 2 * 16 = 60\ \mathrm{g/mole}$. The average molar mass of an *atom* in sand is then $\frac{60}{3}\ \mathrm{g/mole} = 0.02\ \mathrm{kg/mole}$.

18

Correct Response

Wow! Great work! Please take time to look at the solution below. Did you do it the same way?

To find the number of atoms in a sand grain, we can simply divide the mass of the sand grain by the mass of an average atom in the grain. This is a bit like finding the number of households in a city by dividing the population of the city by the average number of people in each household:

$$\text{number of atoms} = \frac{\text{mass of grain}}{\text{mass of atom}} = \frac{\text{volume*density}}{\text{mass of atom}}.$$

Since mass is a product of an object's volume multiplied by its density, we can express our equation as written above. In summary, we will need three quantities to get to our solution: the volume of a sand grain, the density of a sand grain, and the average mass of an atom in the sand grain.

We've seen that $2 \times 10^{-11}\ \mathrm{m}^3$ is a typical volume of a sand grain. Sand sinks pretty quickly, so its density must be rather higher than water but not as high as, say, iron. In fact, the density of quartz is about $2600\ \mathrm{kg/m}^3$. Let's plug these numbers into our equation:

$$\text{number of atoms} = \frac{(2\times10^{-11}\ \mathrm{m}^3)*(2600\ \mathrm{kg{\cdot}m}^{-3})}{\text{mass of atom}}.\quad (1)$$

Great! Now we just need the average mass of an atom in sand. Since we are told that 20 grams (or 0.02 kg) of sand contains 6×10^{23} atoms (1 mole), we can estimate the mass of a single atom in sand, using the 'multiply by one' trick:

$$1\ \text{atom} \times \frac{0.02\ \mathrm{kg}}{(6\times10^{23}\ \text{atoms})} = \frac{0.02}{(6\times10^{23})}\ \mathrm{kg}.\quad (2)$$

Finally, plugging the result of (2) into equation (1) produces:

$$\text{number of atoms} = (2 \times 10^{-11}\ \mathrm{m}^3) \times (2600\ \mathrm{kg} \cdot \mathrm{m}^{-3}) \times \frac{(6\times10^{23})}{(0.02\ \mathrm{kg})} \sim 10^{18}$$

.

Now we have another useful large number: 10^{18} is the number of atoms in a typical grain of sand. We accept 17-19 as correct answers.

Now back to question 1:

You answer will depend on the size of the beach! Victoria's 90 mile beach is (no surprise) 150 km long, and it's wider than Coogee. So, if it has similar depth and if its sand grains have comparable size (I don't know this), it would have about 10^{18} grains, which is very close to our answer! For some large beaches, the numbers are comparable. (But our estimates are not nearly good enough to say they are equal.)

Lesson learned: A grain of sand is both tiny and huge (depending on your point of view!).

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1 / 1 points

5.

[#145] **How big is a meteor?**

Can you tell just by looking with the naked eye? It turns out that, very roughly, yes you can.

This is not a question for this course! It is an interesting puzzle that requires first year university physics, as well as some high school physics we'll cover later. So we don't expect you to do it. However, it was a fun problem for a bunch of physicists as we drove home early one morning, after going out of the city to watch a meteor shower. And we arrived at two different answers, both possibly right. So this link is only for those who think that it would be fun to see a rather more difficult estimation involving more diverse fields of physics: http://www.phys.unsw.edu.au/~jw/meteor.html

But please answer this question: How are you doing?

- I don't want to do any more estimation problems! Enough is enough!
- I love these types of problems! I'll take a look at the recommended website.

  Great! We hope you enjoy the other problems in the course.

- I am indifferent about these estimation problems.
- I'm lost!