

Exercise 1: A bit of math, chemistry and physics

Astronomy requires a foundation of physics and chemistry. In this exercise, you'll go over some of the chemical and physical ideas that recur throughout this course.

Length scales and units

One of the basic aspects of science, in contrast to other "ways of knowing", is the measurement of phenomena. This idea of quantifying immediately leads to the necessity of units; that is, words that describe the measurement and give it meaning.

For instance, one of the crucial distances we'll be talking about this quarter is the distance of a planet from its sun. In our Solar System, we can use a variety of units, from the familiar "kilometers" (abbreviated km) to the more exotic-sounding "astronomical units" (AU). The table below shows the planet-Sun distances using both units:

Planet name	Planet-Sun distance (km)	Planet-Sun distance (AU)		Steps away from Sun
Mercury	57,900,000	0.387		
Venus	108,200,000	0.723		
Earth	149,600,000	1.00		
Mars	227,900,000	1.524		
Jupiter	778,300,000	5.203		
Saturn	1,427,000,000	9.539		
Uranus	2,870,000,000	19.19		
Neptune	4,497,000,000	30.06		
Pluto	5,916,000,000	39.54		
Eris (Xena) (2003 UB13)	14,511,000,000	97.00		

One thing I hope you notice is that kilometers are a cumbersome unit to use, what with all the big numbers. This is the justification for using scientific notation.

1. In the second-from-the-right blank column on the table, convert the numbers in the “kilometers” column into scientific notation.

2. Look at the “AU” column and suggest a definition for 1 AU. (I don’t mean “1 AU = 149,600,000 km”; I can read the table, too. What does 1 AU *represent*?)

3. We are going to make a model of the solar system on the roof of the building. The roof is about 1000 of my steps in length. If we put the Sun at one end of the roof, figure out how many of my steps away each planet will be, and enter this number into the far right blank column on the table.

4. a. The problem is, I’d like to be able to put the Sun and planets in this model at the same scale as the distances between objects. Given that the Sun’s diameter (width) is about **one-hundredth** ($1/100$) the distance from the Sun to the Earth, **how many steps** “wide” will the Sun be on our model. What **common household object** might be used to model the Sun?

b. If you think that’s a problem, then consider that the Earth’s diameter is about one-hundredth that of the Sun. **How many steps** “wide” will the Earth be in the model. Is there any common household object that might be used?

c. So must two different scales be used on our model, one for the distances between bodies and one for the bodies themselves?

Physics

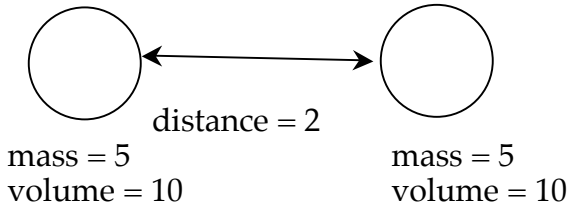
Physics is the scientific study of energy and motion. Physics uses mathematics as a tool to develop theories of energy and motion, though many physics principles can be described without resorting to numbers and equations.

One of these principles is the notion of force, the impetus behind motion. Force may arise from one of four fundamental sources; the one mentioned in the first chapter of the text is **gravity**. The gravitational force is solely **attractive** (no such thing so far as anti-gravity).

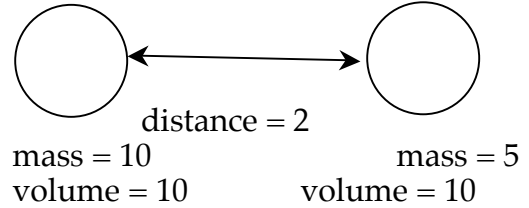
To illustrate the point that math is not necessarily needed to figure out physical situations, consider the three scenarios of pairs of astronomical bodies below.

Each body has its mass and volume specified, and the distance between each pair of bodies is also shown.

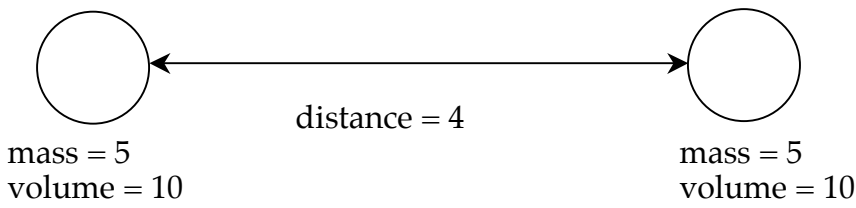
Scenario A:



Scenario B:



Scenario C:



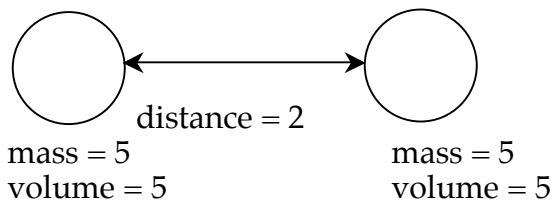
5. In each pair, the body on the right feels a gravitational attraction due to the body on the left. **Order** the scenarios from most gravitational force felt by the body on the right to the least (if you think two scenarios exhibit the same amount of attraction, use an equals sign).

Summarize your findings by filling in the blanks in the statements below with "more" or "less":

More mass on the other body means _____ gravitational force felt.

Greater distance from the other body means _____ gravitational force felt.

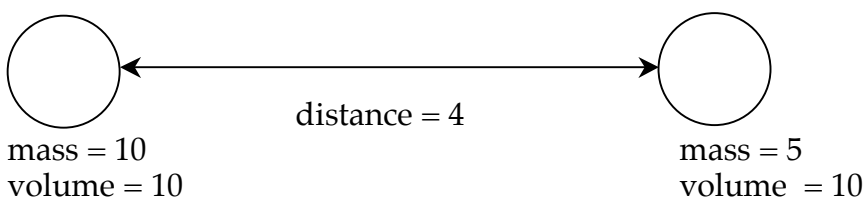
6. Consider this scenario (Scenario D):



Where does the right body's attraction to the left body fit in your order for the previous problem?

It turns out that scenario D exhibits the **same** amount of attraction as scenario A; what does this suggest to you about the importance of “volume” in gravitational attraction?

7. Finally, consider this scenario (Scenario E)



Where does the right body's attraction to the left body fit in your order for the problem 5?

It turns out that scenario E exhibits more attraction than scenario C but less attraction than scenario A; which is the more important factor for gravitational attraction, **mass** or **distance**?

Chemistry

Chemistry is the study of matter and its changes, using the rules of physics. Since ours is a universe of matter, you will need to know a little about these rules of how matter changes. **Atoms** are the smallest unit of matter, but most matter is made of **molecules**. Therefore, you will need a set of simplified rules to describe bonding between atoms to form molecules. Obtain a “ball-and-stick” molecular model kit from the cart.

- The **rules**:
- White balls represent **hydrogen atoms**
 - Red balls represent **oxygen atoms**
 - Black balls represent **carbon atoms**
 - Blue balls represent **nitrogen atoms**
 - The plastic sticks represent chemical bonds (which are merely a pair of shared electrons between atoms); length doesn't matter
 - For a molecule to be "happy" (i.e., have all of its bonding requirements satisfied), all holes must be filled with bonds

8. a. Using two white balls and one plastic stick, make a model of the simplest and most common molecule in the universe — the hydrogen molecule. Therefore, what is the most common **element** in the universe?

b. So a hydrogen atom can only bond to one other atom, maximum. What is the maximum number of atoms that **carbon** could bond to (hint: count holes)? That **oxygen** could bond to? That **nitrogen** could bond to?

c. Why do you suppose there are no **helium** atoms in the kit? Hint: Helium is a "noble" gas.

9. a. Create the following molecules: **water** (H_2O), **ammonia** (NH_3) and **methane** (CH_4). Draw the molecules, as best as you can, below. What are the shapes of these molecules? Select from the following list: "tetrahedral", "bent", "trigonal pyramidal", "linear".

b. By writing the chemical formula CH_4 , what information about methane are you losing (so always keep this loss of information in mind)?

10. Create the molecule CO_2 (carbon dioxide). What type of bonds need to be used to fulfill the "fill every hole" rule? Is there more than one way to do this? The correct structure will not have any oxygen-oxygen bonds. What is the **shape** of carbon dioxide?