Chapter 1

Introduction to the Kontinua Sequence

This book will start you on the long and difficult trek to becoming a modern problem solver. Along the path, you will learn how to use the tools of math, computers, and science.

Why should you bother? There are big problems in this world that will require expert problem solvers. Those people will make the world a better place while enjoying interesting and lucrative careers. We are talking about engineers, scientists, doctors, computer programmers, architects, actuaries, and mathematicians. Right now, those occupations represent about 6% of all the jobs in the United States. Soon, that number is expected to rise above 10%. On average, people in that 10% of the population are expected to have salaries twice that of their non-technical counterparts.

Solving problems is difficult. At some point on this journey, you will see people who are better at solving problems than you are. You, like every other person who has gone on this journey, will think "I have worked so hard on this, but that person is better at it than I am. I should quit." Don't.

First, solving problems is like a muscle. The more you do, the better you get at it. It is OK to say "I am not good at this yet." That just means you need more practice.

Second, you don't need to be the best in the world. 10 million people your age can be better at solving problems than you, *and you can still be in the top 10% of the world*. If you complete this journey, there will be problems for you to solve and a job where your problem-solving skills will be appreciated.

So where do we start?

1.1 Matter and Energy Introduction

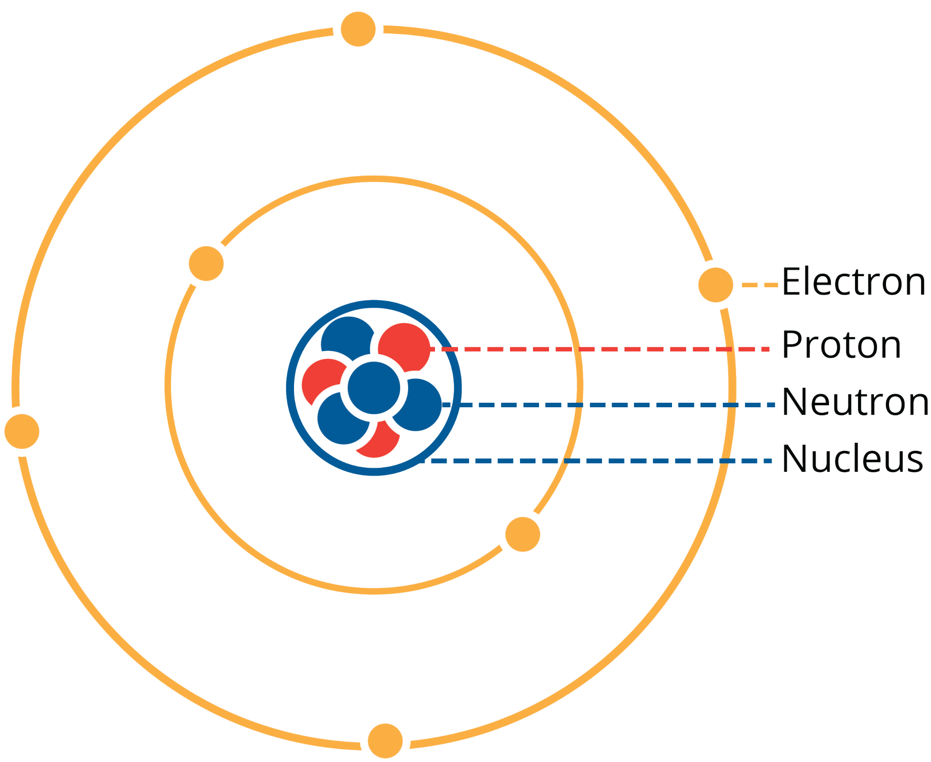
The famous physicist Richard Feynman once asked this question: "If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence was passed on to the next generation of creatures, what statement would contain the most information in the fewest words?"

His answer was "All things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another."

That seems like a good place to start.

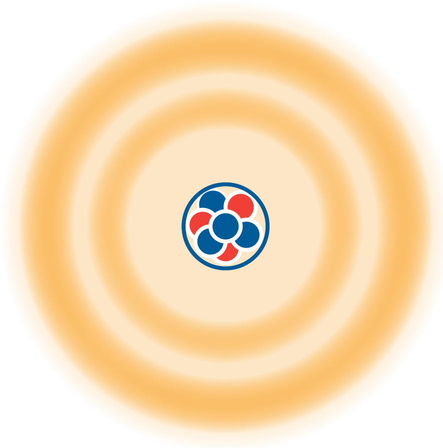
All things (including the air around you) are made of atoms. Atoms are very tiny – there are more atoms in a drop of water than there are drops of water in all the oceans.

Every atom has a nucleus that contains protons and neutrons. There is also a cloud of electrons flying around the nucleus. However, the mass of the atom comes mainly from the protons and neutrons, which are exponentially heavier than electrons.



Watch **Elements and atoms** from Khan Academy at `https://youtu.be/IFKnq9QM6_A`.

The previous graphic is slightly untrue. While it is a convenient model for thinking about atoms, in reality electrons don't neatly orbit the nucleus. Scientists don't know exactly where an electron will be in relation to the nucleus, but they do know where it's most likely to be. They use a cloud that is thicker in the center but fades out at the edges to represent an electron's position.



We classify atoms by the numbers of protons they have. An atom with one proton is a hydrogen atom, an atom with two protons is a helium atom, and so forth (refer to periodic table on pg..). We say that hydrogen and helium are *elements* because the classification of elements is based on proton number. And we give each element an atomic symbol. Hydrogen gets H. Helium gets He Oxygen gets O. Carbon gets C, etc.

Often two hydrogen atoms will attach to an oxygen atom. The result is a water molecule. Why do they cluster together? because they share electrons in their clouds.

A molecule is described by the elements it contains. Water is H_2O because it has two hydrogen atoms and one oxygen atom.

There are many kinds of molecules. You know a few:

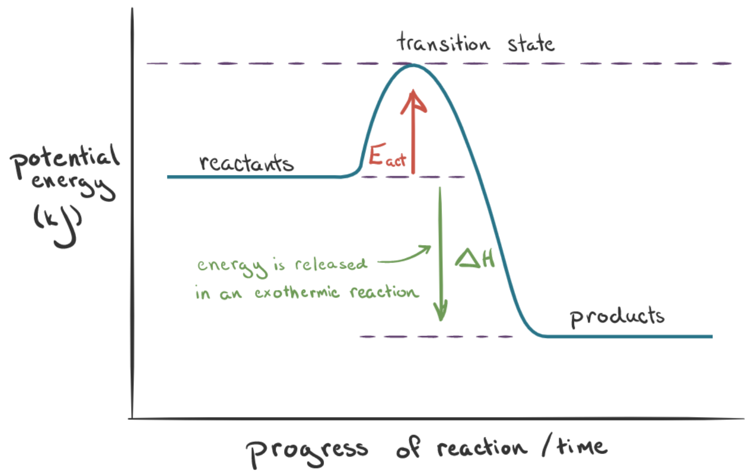
- Table salt is crystals made of $NaCl$ molecules: a sodium atom attached to a chlorine atom.
- Baking soda, or sodium bicarbonate, is $NaHCO_3$.
- Vinegar is a solution including acetic acid (CH_3COOH).
- O_2 is the oxygen molecules that you breathe out of the air (Air, a blend of gases, is mostly N_2.).

1.2 Chemical Reaction

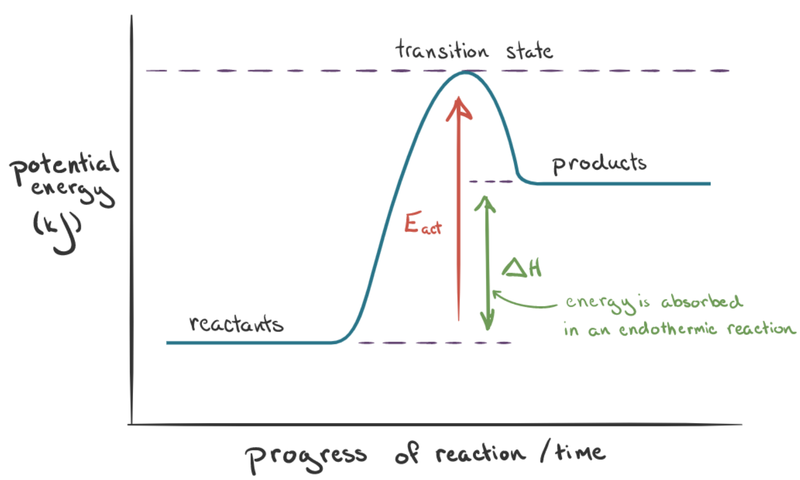
Sometimes two hydrogen atoms form a molecule (H_2). Sometimes two oxygen atoms form a molecule (O_2). If you mix these together and light a match, they will rearrange themselves into water molecules. This is called a *chemical reaction*. In any chemical reaction, the atoms are rearranged into new molecules.

Some chemical reactions (like the burning of hydrogen gas described above) are *exothermic*

– that is, they give off energy. Burning hydrogen gas happens quickly and gives off a lot of energy. If you have enough, it will make quite an explosion.



Other chemical reactions are *endothermic* – that is they consume energy. Photosynthesis, the process by which plants consume energy from the sun to make sugar from CO_2 and H_2O requires an endothermic chemical reaction.



In a chemical reaction, the transition state is the point where there is a maximum value of energy. This energy is called the activation energy.

Here's an overview of chemical reactions: https://simple.wikipedia.org/wiki/Chemical_reaction

1.3 Mass and Acceleration

Each atom has a mass, so everything that is made up of atoms has a mass, which is pretty much everything. We measure mass in grams. A paper clip is about 1 gram of steel. An adult human can weigh 70,000 grams, so for larger things we often talk about kilograms. A kilogram is 1000 grams.

The first interesting thing about mass is that objects with more mass require more force to accelerate. For example, pushing a bicycle so that it accelerates from a standstill to jogging speed in 2 seconds requires a lot less force than pushing a train so that it accelerates at the same rate.

You will probably find it useful to watch Khan Academy's summary of Newton's second law of motion: https://youtu.be/ou9YMWlJgkE

Newton's Second Law of Motion

The force necessary to accelerate an object of mass m is given by:

$$F = ma$$

That is the force is equal to the mass times the acceleration.

What are the units here? We already know that mass is measured in kilograms. We can measure velocity in meters per second, but that is different from acceleration. Acceleration is the rate of change in velocity. So if we want to go from 0 to 5 meters per second (that's jogging speed) in two seconds. That is a change in velocity of 2.5 meters per second every second. We would say this acceleration is $2.5m/s^2$.

What about measuring force? Newton decided to name the unit after himself: The force necessary to accelerate one kilogram at $1m/s^2$ is known as *a newton*.

Exercise 1 Acceleration

While driving a bulldozer, you come across a train car (with no brakes and no locomotive) on a track in the middle of a city. The train car has a label telling you that it weighs 2,400 kg. There is a bomb welded to the interior of the train car, and the timer tells you that you can safely push the train car for 120 seconds. To get the train car to where it can explode safely, you need to accelerate it to 20 meters per second. Fortunately, the track is level and the train car's wheels have almost no rolling resistance.

With what force, in newtons, do you need to push the train for those 120 seconds?

Working Space

Answer on Page 9

1.4 Mass and Gravity

The second interesting thing about mass is that masses are attracted to each other by the force we call *gravity*. The force of attraction between two objects is proportional to the product of their masses. As objects get farther away, the force decreases. That is why you are more attracted to the earth than you are to distant stars, which have much more mass than the earth.

Newton's Law of Universal Gravitation

Two masses (m_1 and m_2) that are a distance of r from each other, are attracted toward each other with a force of magnitude:

$$F = G\frac{m_1 m_2}{r^2}$$

where G is the universal gravitational constant. If you measure the mass in kilograms and the distance in meters. G is about 6.674×10^{-11}. That will get you the force of the attraction in newtons.

Exercise 2 Gravity

Working Space

The earth's mass is about 6×10^{24} kilograms.

Your spacecraft's mass is 6,800 kilograms.

Your spacecraft is also about 100,000 km from the center of the earth. (For reference, the moon is about 400,000 km from the center of the earth.)

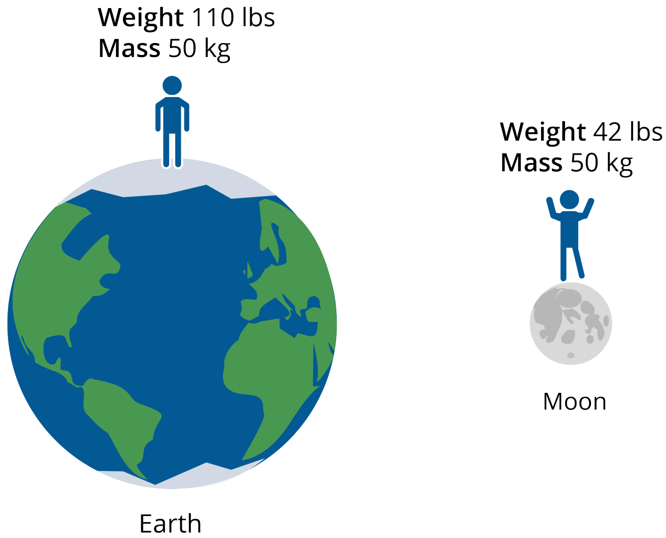
What is the force of gravity that is pulling your spacecraft and the earth toward each other?

Answer on Page 9

1.5 Mass and Weight

Gravity pulls on things proportional to their mass, so we often ignore the difference between mass and weight.

The weight of an object is the force due to the object's mass and gravity. When we say, "This potato weighs 1 pound," we actually mean "This potato weighs 1 pound on earth." That same potato would weigh about one-fifth of a pound on the moon.



But that potato has a mass of 0.45 kg anywhere in the universe.

FIXME Global layout note: Let's discuss adding Title's and Captions to all graphics.

For example:
TITLE: Mass versus Weight
CAPTION: Human Earth weight: 150lbs / Moon weight:??lbs
Potato Earth weight: .25lbs / Moon weight: ??lbs

FIXME: Allison thinks it would be funny if the person in the graphic were holding a potato and we also added the weight and mass of the potato to the caption. No worries if this type of edit isn't in the budget!

FIXME: What are your thoughts about using the metric system consistently – in which case we'll replace pounds here with kilos.

This is a draft chapter from the Kontinua Project. Please see our website (`https://kontinua.org/`) for more details.

Appendix A

Answers to Exercises

Answer to Exercise 1 (on page 6)

To get the train to 20 meters per second in 120 seconds, you must accelerate it with a constant rate of $\frac{1}{6}m/s^2$. You remember that $F = ma$, so $F = 2400 \times \frac{1}{6}$. Thus, you will push the train with a force of 400 newtons for the 120 seconds before the bomb goes off.

Answer to Exercise 2 (on page 7)

$$F = G\frac{m_1 m_2}{r^2} = (6.674 \times 10^{-11})\frac{(6.8^3)(6 \times 10^{24})}{(10^5)^2} = 6.1 \times 10^6$$

About 6 million newtons.

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