Homework #3 Solutions
Due in class Wednesday, February 8

Answer parts 1 and 2 on a separate sheet of paper. You do NOT need to print this to hand it with your answers.

Part 1. Definitions

For each of the terms below, write two sentences. The first sentence should be a definition in your own words, and the second should be an explanation of how this concept is significant in Astronomy.

a) Differential Rotation
Differential rotation is the process by which different parts of a non-solid body rotate at different speeds. In Astronomy, this is relevant because the Sun experiences differential rotation, meaning that it's equator rotates faster than its poles. Because it is made of plasma, which carries a magnetic field, this effect causes the magnetic field of the sun to twist over time.

b) Isotope
Isotopes are atoms of the same element (meaning same number of protons) but different numbers of neutrons in their nucleus. This makes them heavier and, in some cases, radioactive. Isotopes are relevant in astronomy because they are created in intermediate steps of the fusion process in the sun and are important there because they increase the size of the nucleus, making it more likely for two nuclei to collide.

Many of you noted that isotopes are also useful in the context of radioactive dating. While this is certainly true, it is not something we discussed in class.

c) Nuclear Fusion
Nuclear fusion is the process through which two lighter nuclei merge into one heavier nucleus. It occurs only under immense temperatures, densities and pressures, such as those that exist at the center of the sun. It is important in Astronomy not only because it is the source of all of the energy that we receive on Earth from the sun, but because it provides the force that "pushes back" against gravity and allows the sun to maintain hydrostatic equilibrium (neither collapsing nor expanding). It is also the primary way that the universe creates many of the elements that make up the Earth and our bodies as humans, including carbon, nitrogen and oxygen!

d) Convection
Convection is the process through which hot material moves to cold regions and cold material moves to hot regions and is exemplified by a boiling pot of water. It is important in astronomy because the sun's surface also boils. Convection carries energy created by fusion in the interior of the sun to the outer layers.

Because the sun is made of plasma (charged particles), this motion further twists the magnetic field (in addition to twisting caused by differential rotation), sometimes resulting in the creation of sunspots.

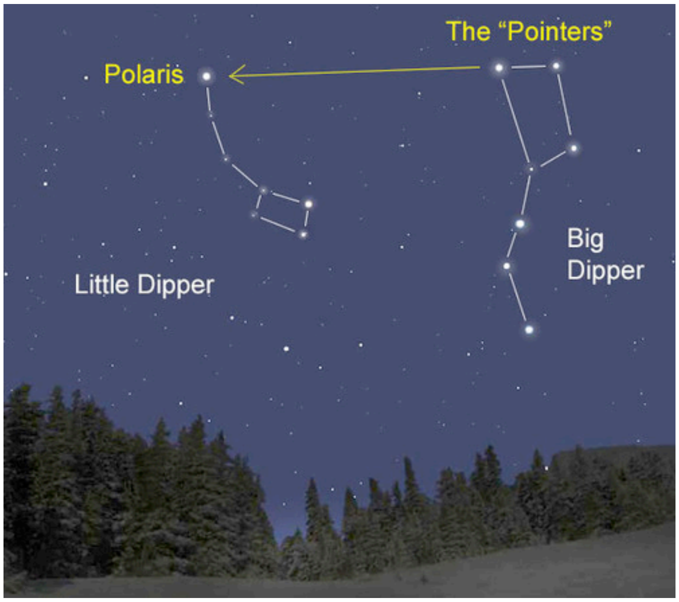
e) Solar Wind
The Solar Wind is the flux of charged particles from the sun that permeate the solar system. Be careful here in that the solar wind is not CREATED by solar flares, it is only strengthened by it. Even a completely inactive sun would launch a solar wind by virtue of the fact that it does not have a solid surface (in other words, there is no "end" to the sun). It is important in astronomy because when the solar wind encounters a planet's magnetic field, the charged particles that make it up are funneled along the magnetic field lines toward the poles where they interact with particles in the Earth's atmosphere and create aurora (northern or southern lights). The frequency and strength of aurora allow us to probe the activity level of the sun.

Part 2. Observing

(a) Using the astrolabe that you made in class (and your planisphere to find it), measure the height of the north star. Record it below.

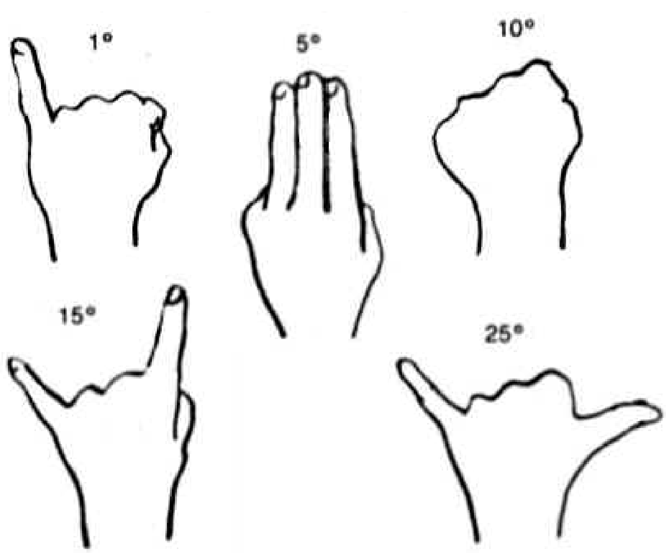
The height of the north star above the horizon is always equal to the observer's latitude, which is 32 degrees here in Tucson. This is why it was used by sailors to navigate for thousands of years – because it height above the horizon tells you where you are relative to the Earth's equator and poles!

You should have gotten a number close to 32. If you didn't, you were either using your astrolabe incorrectly or looking at the wrong star. Don't forget to use your planispheres! The rivet in your planisphere is the north star. Also, don't assume that the north star is the brightest star in the sky. It's definitely not! The only "special" thing about the north star is it's location! Use other recognizable constellations such as the "pointer stars" of the big dipper or Cassiopeia to help you find the north star!



(b) Using the "fist and finger method" outlined in the celestial motions lab (summarized below) record the height of the north star again. State the total and how you arrived at it (ex: two fists + 1 finger = 21 degrees)

Again, this should have been close to 32 degrees



(c) How close are your two measurements? Which do you trust more and why? Write a paragraph outlining your answer.

Probably you should trust your astrolabe more, as it is a much more accurate instrument, however many of you pointed out that the fist and finger method is easier to use.

Part 3. Math Skill #2: Powers of Ten

In science, powers of ten are an important tool for understanding the scale of a number, or its rough size. They are particularly powerful when comparing two quantities, or trying to figure out how much bigger one thing is than another. This can be very important in astronomy, where numbers vary in magnitude from the size of atoms (about 10^{-10} meters) to the size of the observable universe (about 10^{26} meters). Comparing those powers of ten, for example, tells you that the atom is 10^{36}, or 1,000,000,000,000,000,000,000,000,000,000,000,000 times smaller than the universe as a whole.

This skill is also useful, however, in life. For example, you often hear politicians talking about state budgets, government bailouts and the federal deficit in terms of thousands, millions, billions, and trillions of dollars. Understanding what these words mean in terms of powers of ten is a useful tool for understanding how much money you're really talking about, rather than just thinking of them all as really big numbers, which is what we tend to do.

A power of ten is really exactly what it sounds like – the number 10 raised to some power (or "exponent"). The goal of a power of ten is really just to tell you roughly how big something is in terms of how many zeroes there would be if you were to round the number to it's nearest multiple of ten.

In other words, ignoring everything else, is the number you're talking about closer to 10 (10^1) or 100 (10×10 or 10^2)? Is it closer to 10,000 ($10\times10\times10\times10$ or 10^4) or 100,000 (10^5)? 10 billion (10^{10}) or 100 billion (10^{11})?

Here are several things to note about powers of ten:

(1) *We are only talking about so-called "round" powers of ten here, so there are no numbers besides ones or zeroes to worry about. This means that we are indeed rounding, or approximating, our answers in many cases, but that's ok in that we are using powers of ten as a tool to understand the* ***rough*** *size of a number*
(2) *The "power" in the power of ten, is equivalent to the number of zeroes when you write the number out completely, so 10^6 is 1 with 6 zeroes after it, or 1,000,000 (one million!).*
(3) *The "power" in the power of ten could also be thought of as the number of tens you need to multiply together to get the number. To use 10^6 again, this means that 1 million is the same thing as 6 tens multiplied together, or $10\times10\times10\times10\times10\times10=1{,}000{,}000=10^6$*
(4) *This can also extend to negative powers, where a negative power of ten represents dividing the number 1 by that many 10s, rather than multiplying. For example 10^{-1} is $1\div10$ and 10^{-2} is $1\div10\div10$, or $1\div100$.*

Exercise 1: Rounding

For each number listed below, write it as a power of 10 (as in 10^X), write it out completely with all its zeroes and write out the word that we commonly use for this number. Two examples are given below for your reference.

9,988,012	≈	10,000,000	=	10^7	= "ten million"
0.0000000004567	≈	0.0000000001	=	10^{-10}	= "one ten-billionth"

Note that the highlighted symbol above is a "squiggly" equals sign which means "approximately equal to". Using this symbol instead of a regular equals sign means that you're rounding, or approximating, the answer. This distinction is very important!

1,234	≈	**1,000**	=	$\mathbf{10^3}$	= **one thousand**
26.1	≈	**10**	=	$\mathbf{10^1}$	= **ten**
0.783	≈	**1**	=	$\mathbf{10^0}$	= **one**
89.098732	≈	**100**	=	$\mathbf{10^2}$	= **one hundred**
0.003456	≈	**0.001**	=	$\mathbf{10^{-3}}$	= **one thousandth**
89,483,217	≈	**100,000,000**	=	$\mathbf{10^8}$	= **one hundred million**
670,000	≈	**1,000,000**	=	$\mathbf{10^6}$	= **one million**
0.000002	≈	**0.000001**	=	$\mathbf{10^{-6}}$	= **one millionth**

Exercise 2: Comparing Powers of Ten

By comparing the difference in the exponents of two powers of ten, you can easily tell how many times bigger one is than the other. This saves you the trouble of having to write both numbers out and count zeroes. For each of the pairs of powers of ten listed, write a statement (of three sentences) in the format of the examples below where the words/numbers that you should alter are underlined.

Example 1: 10^{9} vs. 10^{6}
10^{9} (1,000,000,000 or one billion) and 10^{6} (1,000,000 or one million) are different by three powers of 10, or 10^{3}.

10^{3} = 1,000 = one thousand, so the powers of ten are telling you that one billion is one thousand times bigger than one million.

To state this another way, one billion is the same as one thousand millions.

Example 2: 10^{-2} vs 10^{2}
10^{-2} (0.01 or one hundredth) and 10^{2} (100 or one hundred) are different by four powers of 10, or 10^{4}.

10^{4} = 10,000 = ten thousand, so the powers of ten are telling you that one hundred is ten thousand times bigger than one hundredth.

To state this another way, one hundred is the same as ten thousand hundredths.

1. 10^{12} vs. 10^{9}

10^{12} (1,000,000,000,000 or one trillion) and 10^{9} (1,000,000,000 or one billion) are different by three powers of 10, or 10^{3}.

10^{3} = 1,000 = one thousand, so the powers of ten are telling you that one trillion is one thousand times bigger than one billion.

To state this another way, one trillion is the same as one thousand billions.

2. 10^{-1} vs 10^{-3}

10^{-1} (0.1 or one tenth) and 10^{-3} (0.001 or one thousandth) are different by two powers of 10, or 10^{2}.

$10^{\underline{2}}$ = 100 = one hundred, so the powers of ten are telling you that one tenth is one hundred times bigger than one thousandth. [1]

To state this another way, one tenth is the same as one hundred thousandths.

3. 10^1 vs 10^5

$10^{\underline{1}}$ (10 or ten) and $10^{\underline{5}}$ (100,000 or one hundred thousand) are different by four powers of 10, or $10^{\underline{4}}$.

$10^{\underline{4}}$ = 10,000 = ten thousand, so the powers of ten are telling you that one hundred thousand is ten thousand times bigger than ten.

To state this another way, one hundred thousand is the same as ten thousand tens.

[1] Note that with this one or any other of these problems, you could also reverse them and use smaller instead of bigger. In this case, that would be "one thousandth is one hundred times smaller than one tenth"