Homework #6
Due in class Wednesday, February 29

You may either print this and write your answers directly on it or answer them on a separate sheet of paper and hand that in.

Part 1: Semester Observing Project Check In

Which project have you chosen and why?

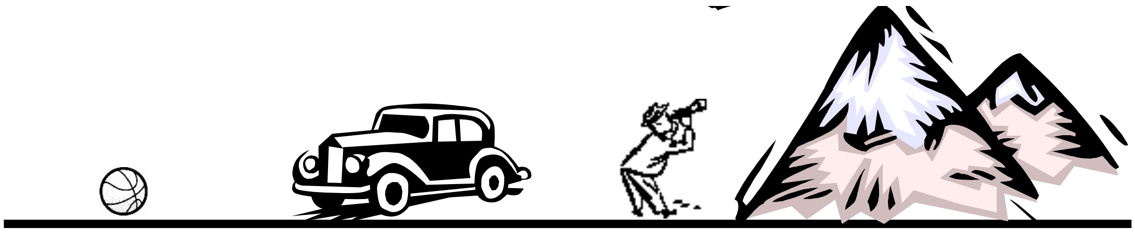
If you’ve already started, describe your progress so far. If you haven’t started yet, lay out a plan for the rest of the semester.

Writs a paragraph describing the procedure for your project **in your own words**

<u>Part 2 - Gravity and Newton's Laws</u>

Exercise #1

Description: The figure below shows several objects (A – D) of different masses located on the surface of the earth.



A **B** **C** **D**

A. Ranking Instructions: Rank (from greatest to least) the strength of the gravitational force exerted by Earth on each of the objects (A – D).

Ranking Order: Greatest 1 ______ 2 _______ 3 _______ 4 ______ Least

Or, the gravitational force exerted on each object is the same. _________ *(indicate with a check mark)*

Carefully explain your reasoning for ranking this way:

B. Ranking Instructions: Rank (from greatest to least) the strength of the gravitational force exerted by each of the objects A – D on Earth.

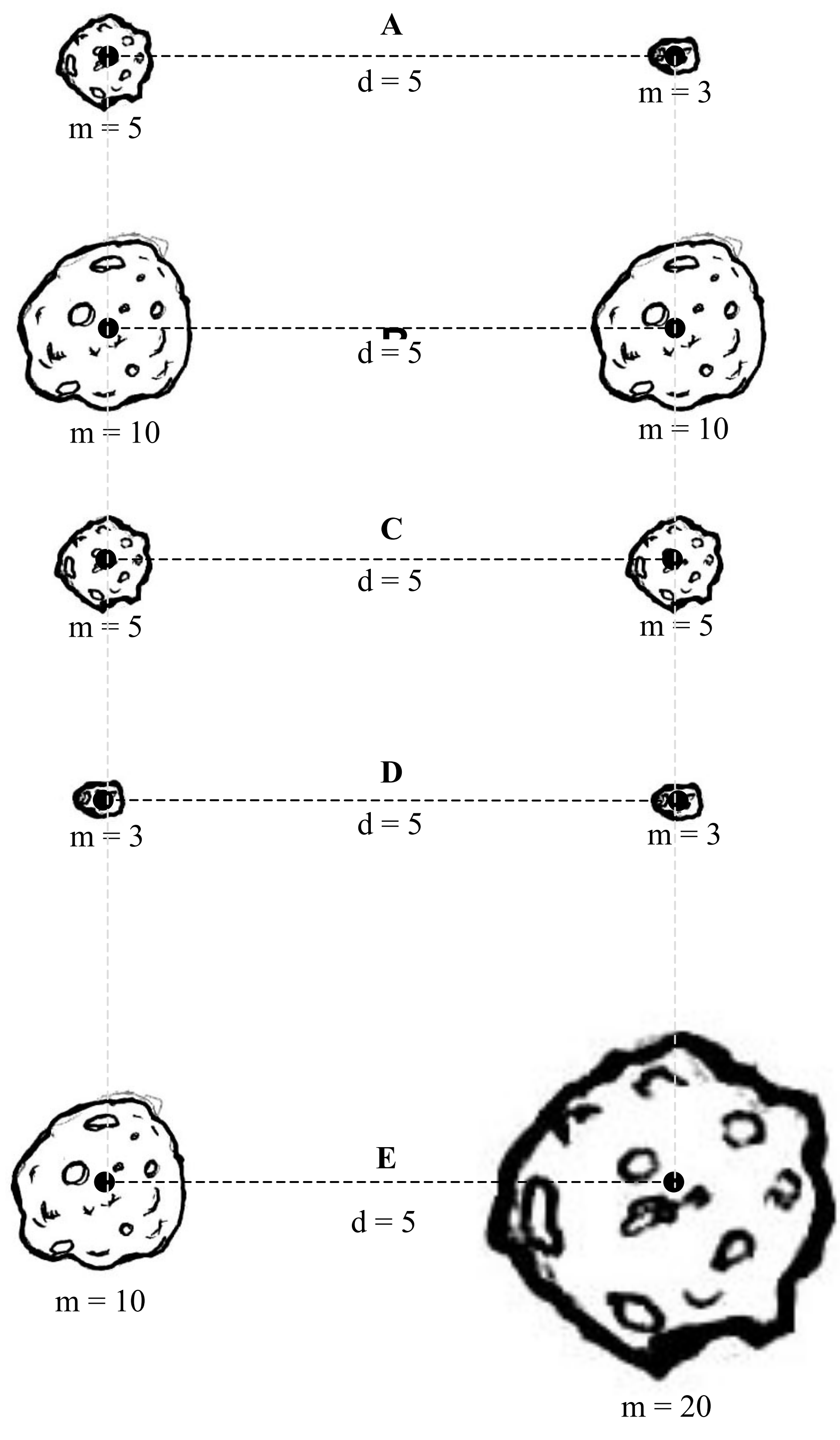
Ranking Order: Greatest 1 ______ 2 _______ 3 _______ 4 ______ Least

Or, the gravitational force exerted by each object is the same. _________ *(indicate with a check mark)*

Carefully explain your reasoning for ranking this way:

Exercise #2

Description: The figures below (A – E) each show two rocky asteroids with masses (m), expressed in arbitrary units, separated by a distance (d), also expressed in arbitrary units.



A. **Ranking Instructions:** Rank (from greatest to least) the strength of the gravitational force exerted on the asteroid located on the left side of each pair.

Ranking Order: Greatest 1 ____ 2 _____ 3 _____ 4 ____ 5 ____ Least

Or, the strength of the gravitational force exerted in each case is the same. _________
(indicate with a check mark)

Carefully explain your reasoning for ranking this way:

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B. **Ranking Instructions:** Rank (from greatest to least) the strength of the gravitational force exerted on the asteroid located on the right side of each pair.

Ranking Order: Greatest 1 ____ 2 _____ 3 _____ 4 ____ 5 ____ Least

Or, the strength of the gravitational force exerted in each case is the same. _________
(indicate with a check mark)

Carefully explain your reasoning for ranking this way:

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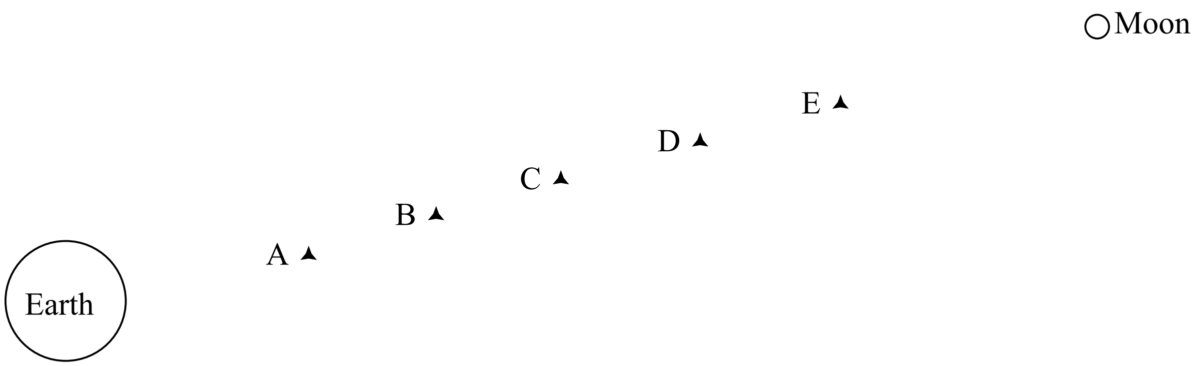
Exercise #3

Description: In the picture below, the Earth-Moon system is shown (not to scale) along with five possible positions (A - E) for a spacecraft traveling from Earth to the Moon. Note that position C is exactly half-way between Earth and the Moon..



A. Ranking Instructions: Rank (from greatest to least) the strength of the gravitational force at positions A - E exerted by the Moon on the spacecraft.

Ranking Order: Greatest 1 ______ 2 _______ 3 _______ 4 ______ 5 ______ Least

Or, the gravitational force exerted at each position is the same. _________ *(indicate with a check mark)*

Carefully explain your reasoning for ranking this way:

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B. Ranking Instructions: Rank (from greatest to least) the strength of the net (or total) gravitational forces at positions A - E exerted by both the Earth and the Moon on the spacecraft.

Ranking Order: Greatest 1 ______ 2 _______ 3 _______ 4 ______ 5 ______ Least

Or, the gravitational force exerted at each position is the same. _________ *(indicate with a check mark)*

Carefully explain your reasoning for ranking this way:

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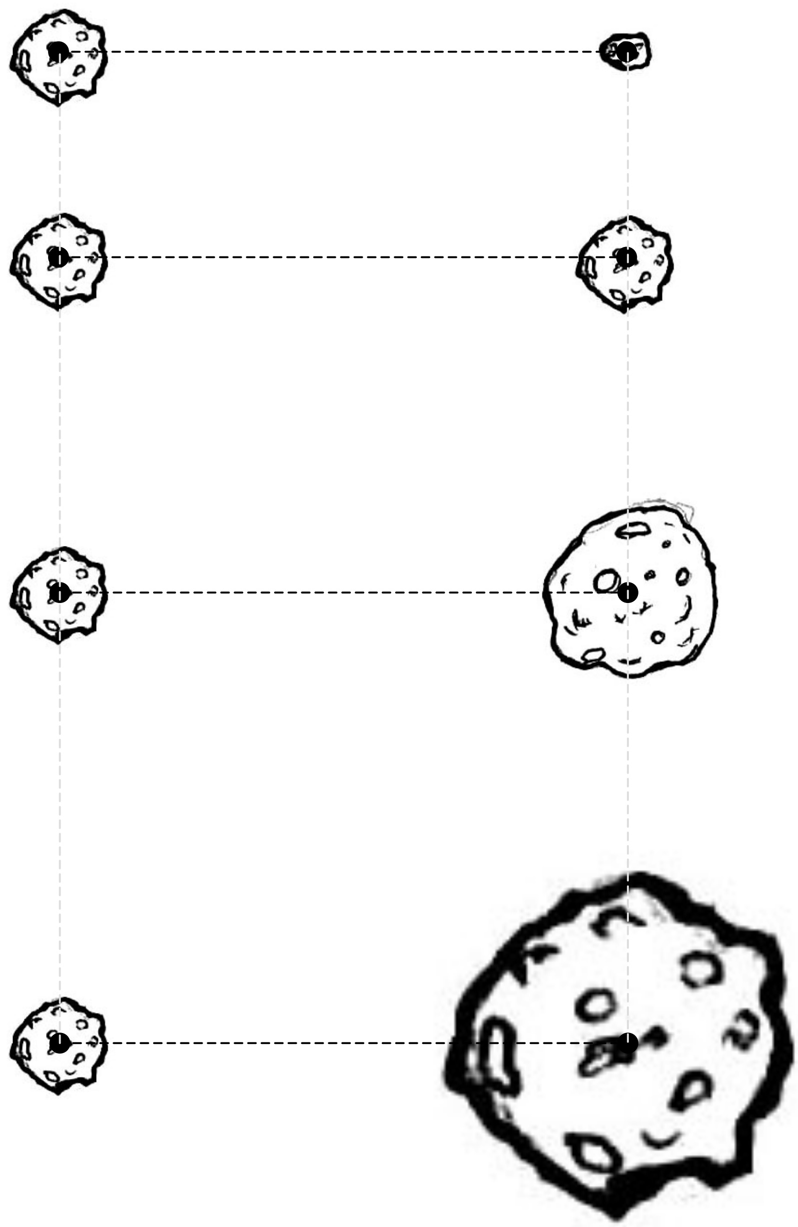
m = 5 d = 5 m = 10

m = 5 d = 5 m = 20

Exercise #4

Description: The figures below (A – D) each show two rocky asteroids with masses (m), expressed in arbitrary units, separated by a distance (d), also expressed in arbitrary units.



A. Ranking Instructions: Rank (from greatest to least) the strength of the gravitational force exerted on the asteroid located on the left side of each pair.

Ranking Order: Greatest 1 ____ 2 _____ 3 _____ 4 ____ Least

Or, the strength of the gravitational force exerted in each case is the same. _________
(indicate with a check mark)

Carefully explain your reasoning for ranking this way:

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B. Ranking Instructions: Using Newton's Second Law, rank the acceleration (from greatest to least) that the asteroids located on the left side of each pair would experience due to the gravitational force exerted on it.

Ranking Order: Greatest 1 ______ 2 _______ 3 _______ 4 ______ Least

Or, the accelerations for each asteroid is the same. _________ *(indicate with a check mark)*

Carefully explain your reasoning for ranking this way:

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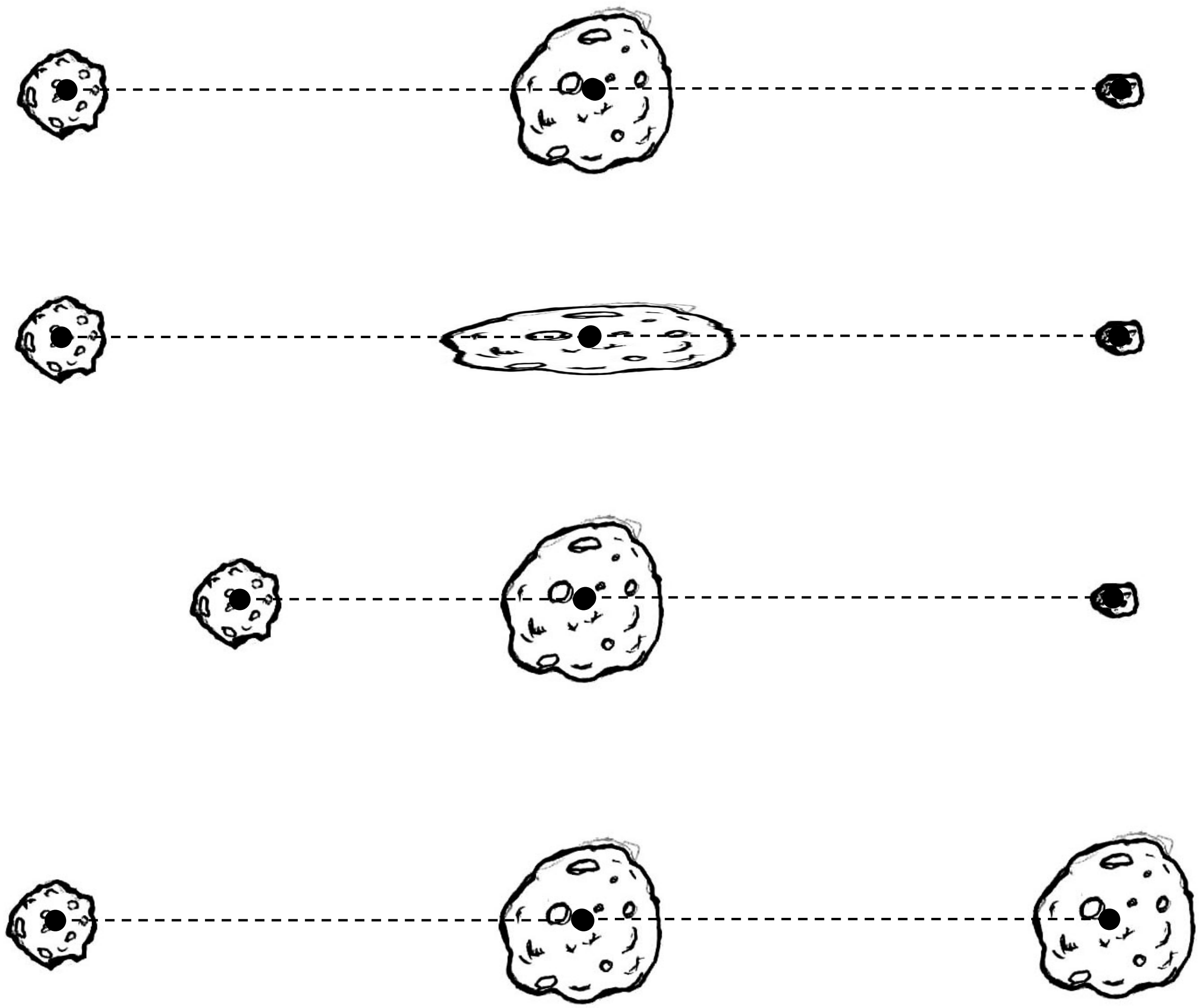
=5 5 m = 5 d = 3 d = 2 m = 10 B A m = 10 d = 3 m = 10 m = 3

m = 10

Exercise #5

Description: The figures below (A – D) each show a large central asteroid along with two other asteroids located to the right and left of the central asteroid. The masses (m) of the asteroids are expressed in arbitrary units, and the distance (d) from the center asteroid is also expressed in arbitrary units.



D

C

Ranking Instructions: Rank (from greatest to least) the strength of the net (or total) gravitational force exerted on the center asteroid by its two neighboring asteroids.

A

Ranking Order: Greatest 1 _____ 2 _____ 3 _____ 4 _____ Least

Or, gravitational forces are all the same strength. _________ (indicate with a check mark)

Carefully explain your reasoning for ranking this way:

B

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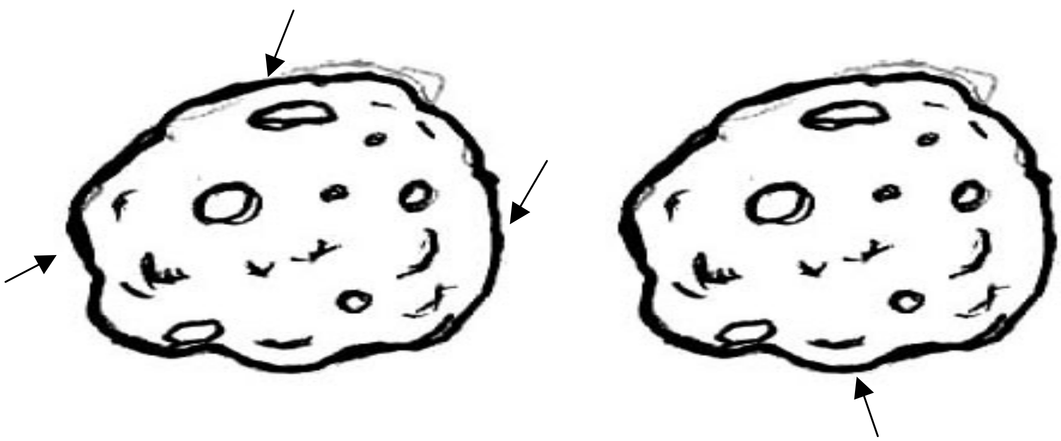
Exercise #6

Description: The figure below shows two identical asteroids located very near one another but moving in an orbit that keeps them from colliding.



Ranking Instructions: Rank (from greatest to least) the net (or total) gravitational force that would be exerted on an astronaut if he/she were standing on the asteroids at the various locations (A – D).

Ranking Order: Greatest 1 ______ 2 _______ 3 _______ 4 ______ Least

Or, the net force exerted on the astronaut would be the same at each location. _________ (indicate with a check mark)

Carefully explain your reasoning for ranking this way:

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Part 3: Math Skill #5: Unit Conversions

Have you ever been asked for your height in centimeters, your weight in kilograms or the speed limit in kilometers per hour? Those of us (Americans) who are used to feet, pounds and miles per hour may not have a good intuition for how large or small, fast or slow, these numbers are, but we can use a tool called the unit conversion to change them into something we're more familiar with.

This is also quite useful in science to change numbers from one unit to another so that we can more easily get a sense for how big or small they are compared to things that we're used to. For example, in Astronomy we often use a unit of distance called the "light year", which is the distance that light travels (remember the speed of light is a constant!) in one year. This is very convenient for measuring the distances between objects in the universe, but as humans, it's hard for us to get a good sense of how big these distances really are unless we can convert them into a unit of distance that we're more familiar with, such as miles or kilometers.

Different countries, branches of science and individuals have different preferences for what units they use to measure things like distance, mass, speed, etc., and so it will often be useful (in science class and in life!) to be familiar with how to switch between them easily. Unit conversions will let you switch between any two units so long as they measure the same thing (distance, for example).

A conversion factor simply utilizes your knowledge of the relationships between units to change from one to another. If you know that there are 2.54 centimeters in every inch, 2.2 pounds in every kilogram[1], or 5280 feet in every mile then converting between them becomes simple arithmetic.

For example, assume that you measure the mass of a meteorite you discovered to be 0.75 pounds and you want to report this remarkable (it's a big one!) discovery to your European colleague. He or she will be more familiar with kilograms, and won't have a good intuition for pounds. If you read the footnote from the last paragraph, you already know that kilograms, which are used in Europe, are by far the better measurement anyway because they are a measurement of mass (rather than gravitational force) and an objects mass will never change no matter where in the universe you go.

Since you live on the surface of the Earth, you can use the conversion factor 1kg=2.2lbs to convert between them. When you use a conversion factor, you are always multiplying the measurement that you want to change by a fraction, where the top and bottom of the fraction are the two pieces on either side of the equals sign in the conversion factor. So the conversion from 0.75lbs to kg becomes:

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[1] Note that this conversion only works on the surface of the Earth because pounds are actually a measurement of gravitational force, while kilograms are a measurement of mass (or the absolute amount of material in something). Thus, this conversion factor, unlike most conversion factors, is only valid on Earth and would be different on the surface of other planets where the gravitational acceleration of objects on the surface will be different from on Earth.

$$\frac{0.75lbs}{1} \times \frac{1kg}{2.2lbs} = 0.45kg$$

Notice that something very convenient just happened here based on how this calculation was set up. You end up with inches on both the top and bottom and, as is always true in algebra when you have the same quantity in both the top and bottom of a fraction, they cancel each other out. This is fine because you didn't want them around anymore anyway! The whole point of the conversion factor is to get rid of an undesirable unit and transform it into a desirable one without breaking any rules.

Notice that we said before that your conversion factor will always be one side of the conversion factor over the other, but didn't say which goes on top and which goes on bottom. This is because unit conversions can be used either way, but only one way will give you the desired outcome so, like most of the math skills we've been dealing with this semester, you need to use logic and intuition to decide which to use.

For example, we had two choices to go between pounds and kilograms (either 2.2lbs/1kg or 1kg/2.2lbs), and the one to choose was the one with pounds on the bottom so that they would cancel out. Had we chosen the other conversion factor we would have ended up with:

$$\frac{0.75lbs}{1} \times \frac{2.2lbs}{1kg} = 1.65\, {}^{lb^2}\!\!/_{kg}$$

Note that this does not simplify your life at all, because none of the units went away by choosing to put pounds on the top of the fraction and kilograms on the bottom. If you ever end up with more complicated units after employing a conversion factor, try going back and flipping the top and the bottom. Unit conversions should always leave you with the same number of units that you started with!

In general, multiplying one number by another changes the number that you are trying to study, and note that in doing this conversion you took a number (0.75kg) and multiplied it by something (1kg/2.2lbs) to get another number (0.45kg). Should that be allowed? Didn't you just change the number you started with into something else entirely? People are often rightfully suspicious of conversion factors at first. In some ways, they seem a little magical, but remember that science always follows the rules of logic (not magic!) and unit conversions, as a tool of science, are no different.

To convince yourself that you can safely use these conversion methods, recall another rule of arithmetic, stating that you can multiply any number by 1 and you will always get back the number you started with. For example, I can multiply 3 by 1 as many times as I want and it will still always be 3. The same is true no matter how big or small the number I started with. Now look more closely at the conversion factors. 2.2 pounds and 1 kilogram are exactly the same thing! Multiplying a number by 2.2lb/1kg or 1kg/2.2lb is really no different than multiplying that number by 1 since both the top and bottom of each fraction are two different ways of saying the exact same thing.

Below are some useful conversion factors for Astronomy, followed by some practice problems to get you started.

<u>Some Useful Conversion Factors</u>
2.54cm = 1in
12in = 1ft
5280ft = 1mi = 1609 m
3.1mi = 5km
1 hr=3600 sec
1 day = 24 hr
1 year = 365.25 days

<u>Special Conversion Factors for Astronomy</u>
1 "Astronomical Unit" (AU) = 1.50 x 10^8 km
1 light year = 9.46 x 10^{12} km
1 parsec = 3.26 light years
1 arcminute = 1/60 degree
1 arcsecond = 1/3600 degree

Note 1: all of the conversion factors listed are units of distance or time. In this class, we will mostly be measuring and manipulating distances, times and velocities/speeds (which have units of distance/time)

Note 2: The metric system prefixes that we've been working with can also conveniently be made into conversion factors, for example 1000m=1km, or 10^6sec=1Msec

Show your work for all practice problems and express your answer in scientific notation and with a unit attached!

1. Alpha Centauri, the closest star to the Sun, is 4.365 light years away. How far away is that in miles?

2. How many seconds are in one year? Give your answer in scientific notation!

3. How many mm are in 1km?

4. Neptune, the most distant planet from the sun in our solar system, is 40AU from the sun.
   a. How far is that in meters?

   b. How far is it in miles?

   c. How far is it in light years?

   d. How far is it in light hours?

5. The moon subtends (takes up) an angle of 0.54 degrees in the sky. How big is that in arcseconds? (note: the moon is very large in the sky compared to most of the things we'll be talking about in this class, so arcseconds are usually what we'll use to talk about angles in the sky!)