Homework #6 Solutions
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.

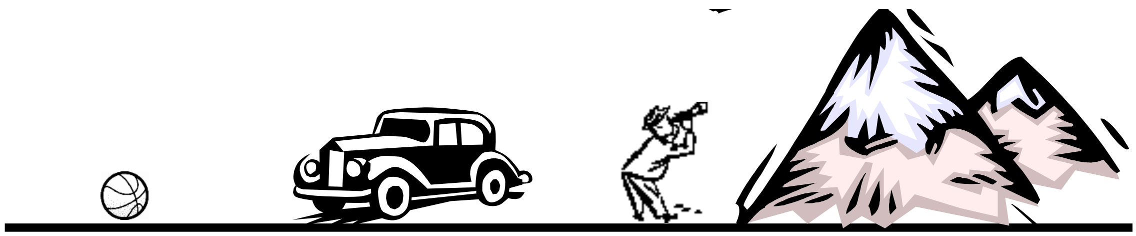
Part 1: Semester Observing Project Check In

I'm just looking for some indication that you've thought about your semester observing project and have planned something feasible. DO NOT WAIT UNTIL THE END OF THE SEMESTER!! Detailed descriptions of all possible projects are available on the course website.

Part 2 - Gravity and Newton's Laws

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 _**D**__ 2 __**B**__ 3 __**C**__ 4 _**A**__ Least

Carefully explain your reasoning for ranking this way:

Since all objects on the surface of Earth are (approximately) the same distance away from the center of the Earth the gravitational force will be proportional to how much mass the two objects (Earth and the object it is attracting) have, hence the mountain feels the greatest gravitational force and the basketball feels the weakest. Note: the key here is that BOTH masses (the mass of the Earth and the mass of the object) factor into the equation $F_g=Gm_1m_2/r^2$, so more massive objects feel a stronger gravitational pull.

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

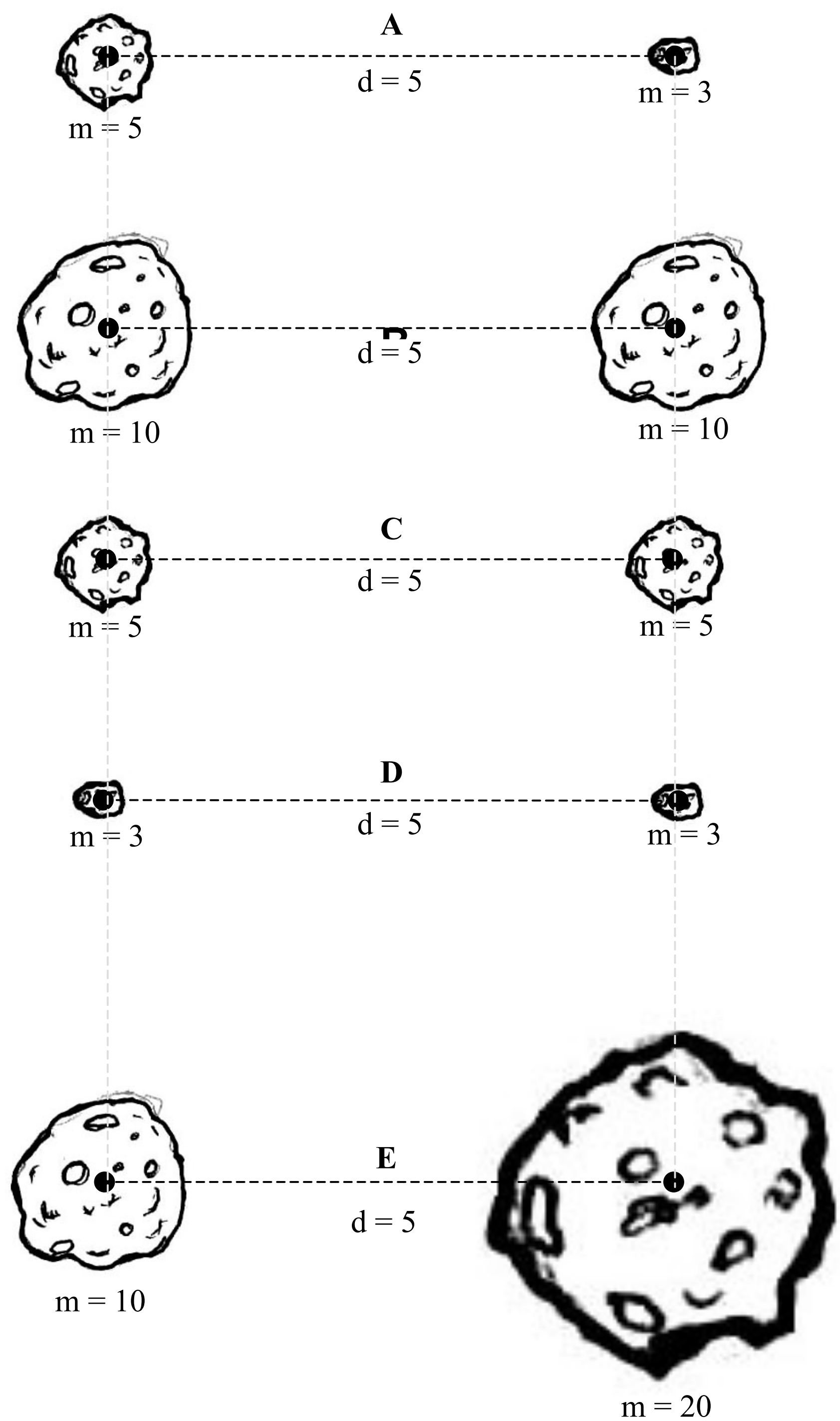
Ranking Order: Greatest 1 _**D**__ 2 __**B**__ 3 __**C**__ 4 _**A**__ Least

Carefully explain your reasoning for ranking this way:

Using Newton's third Law, for example, the Mountain exerts a gravitational force on the Earth with the same strength as the Earth exerted on the Mountain. So the ranking for Part A and Part B must be the same.

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 _E_ 2 _B_ 3 _C_ 4 _A_ 5 _D_ Least

Carefully explain your reasoning for ranking this way:

Noting that the distance between the asteroids in each pair is the same, the ranking can be made based on the amount of mass that each pair of asteroids has, so two large asteroids exert a strong gravitational force on each other and two small asteroids exert a weak gravitational force on each other. Note that in the formula for the strength of the gravitational force $F_g=Gm_1m_2/r^2$, the two masses multiply together (they don't add)

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.

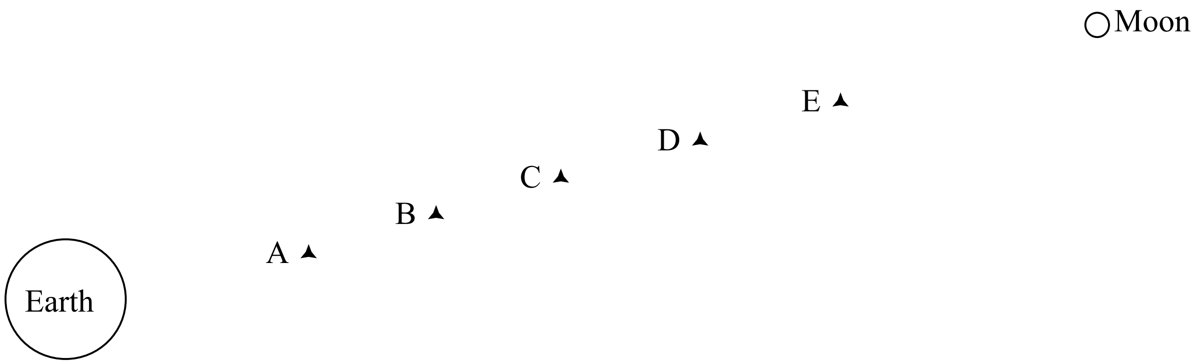
Ranking Order: Greatest 1 _E_ 2 _B_ 3 _C_ 4 _A_ 5 _D_ Least

Carefully explain your reasoning for ranking this way:

From Newton's Third Law, the force on the asteroid on the left by the asteroid on the right has to be exactly equal in strength to the force exerted by the asteroid on the right by the asteroid on the left. So the ranking from Part A and Part B must be identical.

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 _E_ 2 _D_ 3 _C_ 4 _B__ 5 _A_ Least

Carefully explain your reasoning for ranking this way:
Since the mass of the Moon and the spacecraft are not changing only the distance between the two objects will affect the strength of the gravitational force. When the spacecraft is closest to the moon, it will feel the strongest for and when it is farthest away it will feel the weakest force.

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.

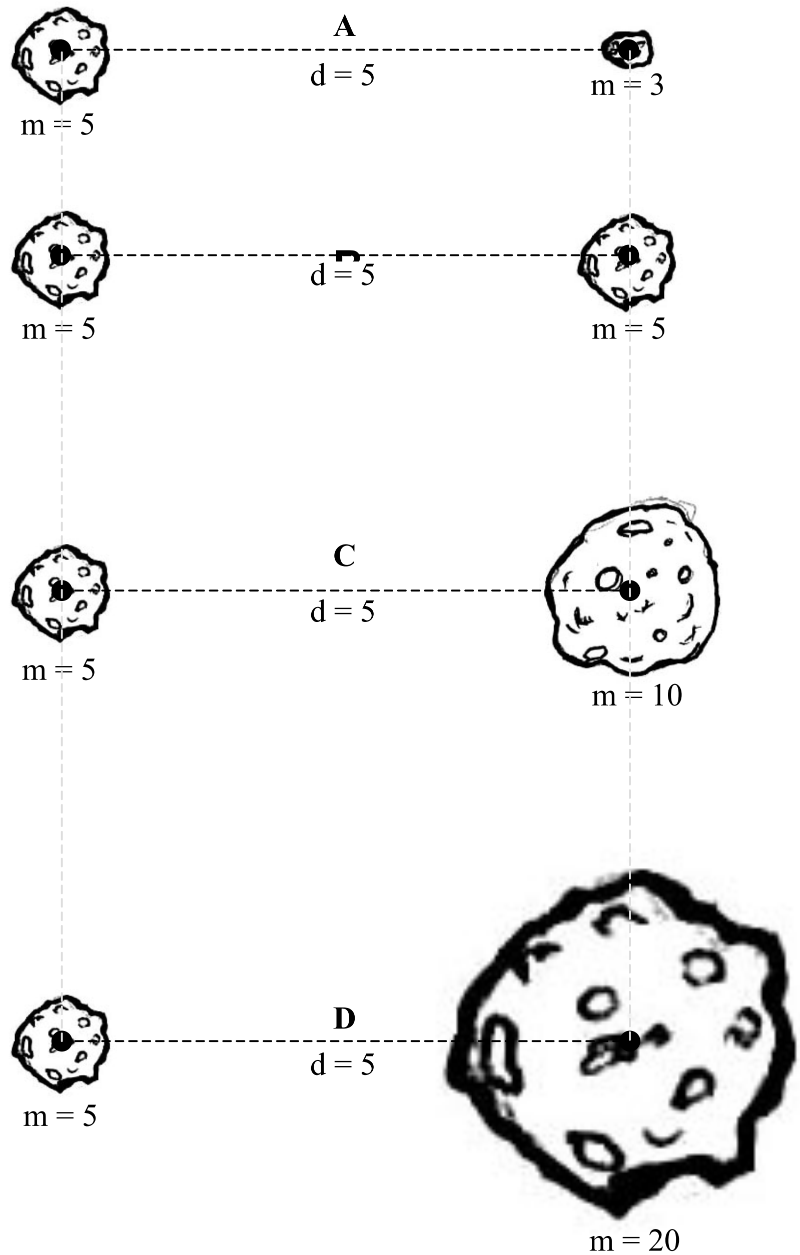
Ranking Order: NOTE THERE ARE (at least) TWO POSSIBLE CORRECT RANKINGS THAT CAN BE GIVEN.
(1) Greatest 1 _A_ 2 _B_ 3 _C_ 4 _D_ 5 _E_ Least
(2) Greatest 1 _A_ 2 _B_ 3 _C_ 4 _E_ 5 _D_ Least

Carefully explain your reasoning for ranking this way:

One of the locations (D or E) could correspond to the situation where the force on Spacecraft by the Moon and the force on the Spacecraft by Earth are equal in strength, and opposite in direction, which would cancel each other out creating a total force of the space of "Zero", which would be the least the total force could ever be. The closest the Spacecraft is to the Earth (location A) corresponds to the place where the force by the Earth would be greatest and the resulting total force would also be greatest at this position because the Moon would simultaneously be exerting its weakest force on the spacecraft.

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 _D_ 2 _C_ 3 _B_ 4 _A_ Least

   Carefully explain your reasoning for ranking this way:
   Noting that the distance between the asteroids in each pair is the same, the ranking can be made based on the product of the two masses for each pair of asteroids, so two large asteroids exert a strong gravitational force on each other and two small asteroids exert a weak gravitational force on each other.

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 _D_ 2 _C_ 3 _B_ 4 _A_ Least

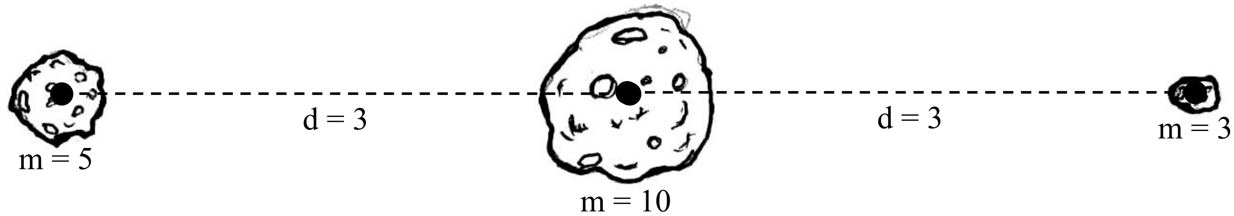
   Carefully explain your reasoning for ranking this way:

   From Newton's Second Law, (total or net Force = mass x acceleration), and noting that the mass of all the asteroids on the left have the same mass, we can infer that the asteroid that is being pulled by the greatest gravitational force will also experience the greatest acceleration. In other words, the rankings follow part (a) for the gravitational force.

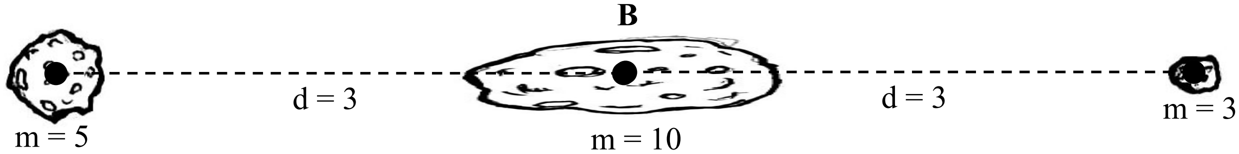
Exercise #5

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.

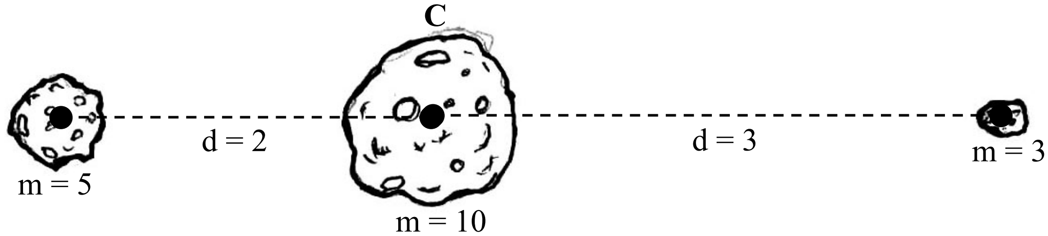
A



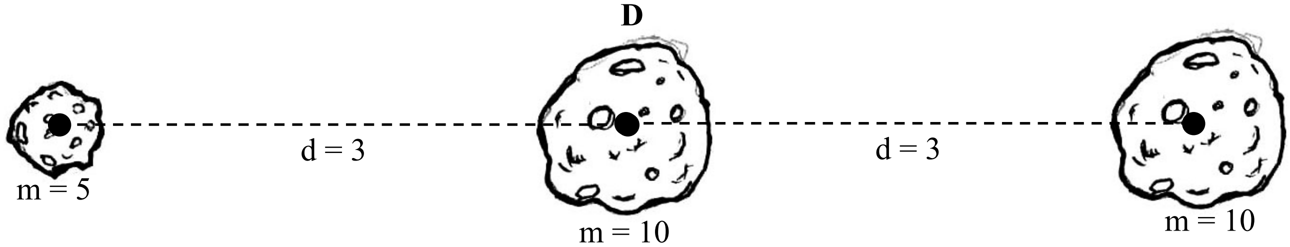
B



C



D



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.

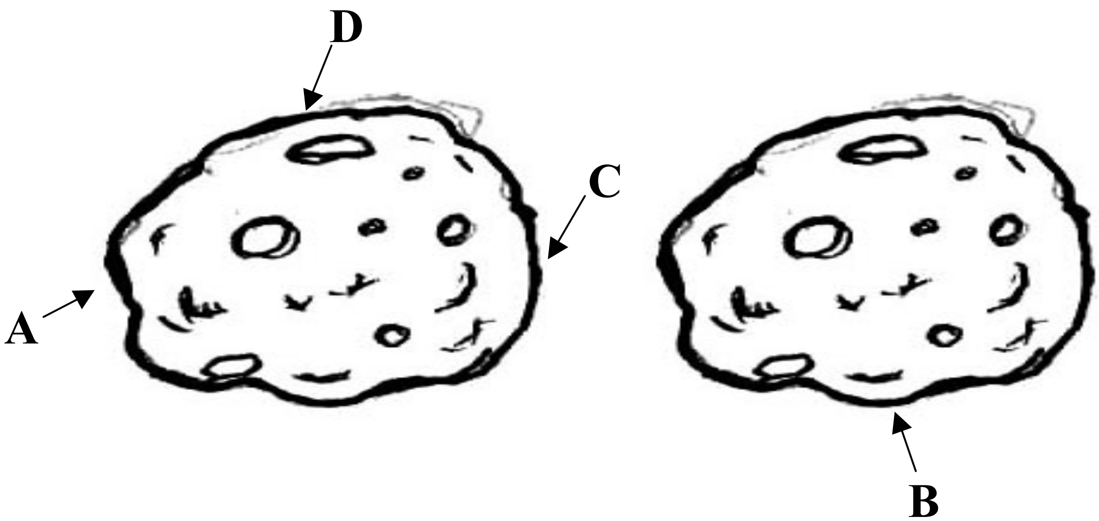
Greatest net force 1 <u>C</u> 2 <u>D</u> 3 <u>A =B</u> Least net force

Carefully explain your reasoning for ranking this way:

To determine the net force on each of the center asteroids, you must consider how the gravitational force exerted by the left asteroid (on the center asteroid) and the gravitational force exerted by the right asteroid (exerted on the center asteroid) would simultaneously act on the central asteroid together. For instance a force to the left of "10" and a force to the right of "7" create a net or total force on the central asteroid of "3" to the left. The strength of each gravitational force on the center asteroid is found by multiplying the masses of the two objects together and then dividing by the distance they are apart squared – Fgrav ~ Mm/d^2. Considering the relative strength of the force on the central asteroid due to the right and lefthand asteroids will lead you to the relative strength ranking. Note that the SHAPE of the Asteroid does not matter (as in A and B).

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).

Greatest net force 1 <u>A</u> 2 <u>B = D</u> 3 <u>C</u> Least net force

Carefully explain your reasoning for ranking this way:

By adding the gravitational force exerted on the astronaut by the left asteroid and the right asteroid the net force can be determined. Note that at position "A" the two gravitational forces are in the same direction (and therefore produce a large net force) while the two forces exerted on the astronaut at position "C" would be in opposite directions (and therefore produce a weak net force) At positions B and D you have the situation where the astronaut would feel a gravitational force toward the center of the asteroid they are landing on and another gravitational force toward the center of the other asteroid. Together these two gravitational forces would produce a net force that is - down and to the right for case D, or up and to the left for case B. In either case the net force on Band D would be weaker than at position A and stronger than at position C.

Part 3: Math Skill #5: Unit Conversions

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?

$$\frac{4.365 lyr}{1} \times \frac{9.46 \times 10^{12} km}{1 lyr} \times \frac{3.1 mi}{5 km} = 3 \times 10^{13} mi$$

OR

$$\frac{4.365 lyr}{1} \times \frac{9.46 \times 10^{12} km}{1 lyr} \times \frac{1000 m}{1 km} \times \frac{1 mi}{1609 m} = 3 \times 10^{13} mi$$

Note that for this and all other unit conversions, it doesn't matter how many conversion factors you use, which ones you use, or in which order you use them. ANY LEGITIMATE UNIT CONVERSION will give you a correct answer. I will list several options for each of the problems in this assignment, but note that they are not the only possibilities!

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

$$\frac{1\text{yr}}{1} \times \frac{365.25\text{day}}{1\text{yr}} \times \frac{24\text{hr}}{1\text{day}} \times \frac{60\text{min}}{1\text{hr}} \times \frac{60\text{sec}}{1\text{min}} = 3.1558 \times 10^{7}\text{ sec}$$

OR

$$\frac{1\text{yr}}{1} \times \frac{365.25\text{day}}{1\text{yr}} \times \frac{24\text{hr}}{1\text{day}} \times \frac{3600\text{sec}}{1\text{hr}} = 3.1558 \times 10^{7}\text{ sec}$$

OR

$$\frac{1\text{yr}}{1} \times \frac{525{,}600\text{ min}}{1\text{yr}} \times \frac{60\text{sec}}{1\text{min}} = 3.154 \times 10^{7}\text{ sec}$$

Note: The reason that this final answer is "off" is because the 525,600min=1yr conversion (which some of you may recognize from the musical Rent) is based on the assumption that 1yr=365days=525,600min (Note that you could verify this with a unit conversion). You know based on the above that if we are to state it more precisely, there are actually 365.25 days in one year. What you have discovered here is that answers will vary based on the precision to which you measure them. We will discuss precision and accuracy, and how to properly round your answers, in another math skill activity in a few weeks. In the meantime, pay attention to how I've rounded all of these problems and see if you can identify a pattern.

3. How many mm are in 1km?

$$\frac{1\text{km}}{1}\times\frac{1000\text{m}}{1\text{km}}\times\frac{1000mm}{1\text{m}}=1\times10^{6}mm$$

OR

$$\frac{1\text{km}}{1}\times\frac{1000\text{m}}{1\text{km}}\times\frac{100cm}{1\text{m}}\times\frac{10mm}{1cm}=1\times10^{6}mm$$

OR

$$\frac{1\text{km}}{1}\times\frac{10^{6}\text{mm}}{1\text{km}}=1\times10^{6}mm$$

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?

$$\frac{40\text{AU}}{1}\times\frac{1.5\times10^{8}\text{km}}{1\text{AU}}\times\frac{1000\text{m}}{1\text{km}}=6.0\times10^{12}m$$

b. How far is it in miles?

$$\frac{40\text{AU}}{1}\times\frac{1.5\times10^{8}\text{km}}{1\text{AU}}\times\frac{3.1mi}{5\text{km}}=3.7\times10^{9}mi$$

OR

$$\frac{6.0\times10^{12}m}{1}\times\frac{1mi}{1609m}=3.7\times10^{9}mi$$

c. How far is it in light years?

$$\frac{40\text{AU}}{1}\times\frac{1.5\times10^{8}\text{km}}{1\text{AU}}\times\frac{1lyr}{9.46\times10^{12}\text{km}}=6.3\times10^{-4}lyr$$

d. How far is it in light hours?

$$\frac{40\,\text{AU}}{1} \times \frac{1.5\times10^{8}\,\text{km}}{1\text{AU}} \times \frac{1\,lightyr}{9.46\times10^{12}\,\text{km}} \times \frac{365.25\,day}{1\,yr} \times \frac{24\,hr}{1\,day} = 5.6\,hr$$

OR

$$\frac{6.3\times10^{-4}\,lightyr}{1} \times \frac{365.25\,day}{1\,yr} \times \frac{24\,hr}{1\,day} = 5.6\,hr$$

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!)

$$\frac{0.54\,\text{deg}}{1} \times \frac{1\,\text{arcsec}}{\frac{1}{3600}\,\text{deg}} = 1.9\times10^{3}\,\text{arcsec}$$

note that when you divide by a fraction in the denominator, it is equivalent to multiplying by the bottom of that fraction. You also may have realized that saying 1arcsec=1/3600deg is the same as saying 3600arcsec=1deg, in which case you could do:

$$\frac{0.54\,\text{deg}}{1} \times \frac{3600\,\text{arcsec}}{1\,\text{deg}} = 1.9\times10^{3}\,\text{arcsec}$$