Around 1600 a young man named Johannes Kepler came to work for an astronomer named Tycho Brahe. Brahe had just spent several decades compiling extremely precise astronomical data. Kepler wasn't so interested in astronomy as in math, but all those years worth of data appealed to him. After studying the data for 22 years, he came up with 3 laws of planetary motion:
1. Orbits around planets are not in fact circular, but are elliptical. (A circle is an ellipse with a factor of 1.0. The earth's orbit is about .98, which is almost perfectly circular - we are actually closer to the sun during our winter.)
2. A line drawn from the sun to the planet will sweep out equal areas in an equal time period, which means that when the planets are closest to the sun, they are also moving the fastest. Farther = slower. Doesn't make too much difference with us, but with pluto, who has a very eccentric orbit, it is very significant.
3. $r^3/T^2 = k$ which means if you know the orbital radius and period, and apply his formula, you will always get the same number (k = constant) as long as all objects are orbiting the same object. So for all objects orbiting the sun, we can know they will have the same "k," so when a comet appears, and we know the period, we can easily calculate the average radius of orbit. Same for anything orbiting the earth, but with a different "k" value of course.

A short time later, Galileo Galilei came on the scene. He derived all the acceleration formulas we learned in Unit 2, and while he didn't actually invent the telescope, he did refine it to the present model, and greatly improved its defining ability. With his newly refined telescope, he was able to see Jupiter's spot, moons orbiting around it, and the rings of Saturn, all of which helped others to see that perhaps the earth was NOT the center of the universe. (It's really ME, of course!) Galileo asked the all important question, "**Why** Do Things Fall?" to which of course you would answer "because of gravity" which actually didn't address the question at all.

Galileo wasn't the first person to notice that things did in fact fall, and he wasn't the guy to first call that concept gravity. Having a name for it doesn't explain WHY it happens, only that we recognize that it does indeed occur. It would still occur if we called it "Melvin" and we wouldn't be any closer to figuring it out. "Why did you fall off the building?" "Melvin." "He pushed you?" "No, Melvin only pulls..."

Galileo obviously knew that when you trip, you fall, but WHY does everything fall toward the earth? Why don't things go sideways? How far out does this pull go? All good questions, none of which is answered by saying "Melvin." He never figured out the answer either. (Galileo, not Melvin)

As Galileo aged, he took on a student named Isaac Newton. You may have heard of him. Newton took on Galileo's question. HE pondered, as apples fell in his orchard, that perhaps that same Melvin could pull all the way out to the moon, and to the sun, and that Melvin could in fact be the reason the earth continues in it's mostly circular orbit around the sun... So he hypothesized that gravity was a property of mass. The more mass, the more gravity. He also saw that the farther you were from the object's mass, the smaller the pull - an inverse relationship! but one tied in with the square of the distance. This continued out indefinitely... to the farthest reaches of the universe, so it seems. The formula he came up with looked like this:

$$F_g \propto m_1 m_2/d^2$$

Which means the gravitational force is proportional to the product of the two masses divided by the square of the distance between the center of the two masses. Simple right? So why the fishy thing in the middle instead of an = sign? Simply speaking, that's all he could get out of the deal. To change a proportional equation into an equality, you need to be able to input a constant, some number that never changes in the equation (like π), but he was never able to measure this value. It wasn't until 1798 - 150 years later! - that a man named Henry Cavendish figured out a way to set up an experiment to test Newton's theory. Up to that time, Newton had only astronomical data to back him up.

Cavendish determined the constant "G" to be 6.67×10^{-11} Nm^2 / kg^2 (OK, I'm lying, N, m and kg came later, but if he HAD used the metric system, that's the number he'd have calculated.) This converted Newton's proportional into the following equality:

$$F_g = Gm_1 m_2/d^2$$

G is always the same number given before. F_g is always in N, m in kg and d in m... F_g is **NOT** F x g. it's gravitational force like F_a is applied force.

While Newton DID call gravity a property of mass, he really didn't explain WHY masses pull on each other... that idea was the next expanded on (without quite being explained either) by Einstein, who said that gravity was a property of space, not mass. Space, he said, is bent in the presence of mass: the more mass, the bigger the bend. I know Ph.D.'s that don't believe gravity exists at all... (this may be true!) but you DO realize that Ph.D. stands for Piled Higher and Deeper...

If you want to figure out what gravity's acceleration is anywhere, you modify the above equation to become:

$$g' = Gm_e/r^2$$

G is always the same number given before. m_e is the mass of the earth, or whatever planet you are on, r is the radius in m, It used to be the distance between the masses, but if you are on a planet, the radius is the distance between you and the center of the planet. If you orbit above the planet, the "r" is the planet radius + the distance above the planet.

This should help you understand the gravitational issue a bit...

xxoo, me

Now work cooperatively to get as much done as you can with Problems B&C for next time, when I'll fill in the gaps. These equations are pretty easy.