

AST 101 ANSWERS TO ASSIGNMENT 3

CHAPTER 5 "Newton, Einstein, and Gravity"

Questions

1. If Aristotle's assertion that the elements of earth and water sought the center of the universe AND the earth were NOT at the center, then simple experimentation would show that material objects and water, when dropped, would take off in some direction OTHER THAN down to the center of earth. Since materials of these two Greek elements DO drop straight down to the earth's center, then, "there you go," Aristotle might say—proof positive that earth is indeed at the center of everything. A logical, but fallacious, argument because of the error of his premise—that elements of earth and water seek the center of the universe. Today's science recognizes even the simplistic limitation of his definition of element, along with the baselessness of his assertion that they seek the center of the universe. It is important that you know that you can be presented arguments which are logical, but are false in their conclusions because of error in their premises.

3. This is not demonstrable on the earth because there is another influence (force) on the experiment of dropping a hammer and feather—frictional drag induced by the air. Take away the air and both would drop at the same rate of acceleration. The moon has no atmosphere, so the law of gravity can be demonstrated there.

4. Mass is the measure of the quantity of matter. Matter is composed of atoms, which have the property of taking up space and having inertia—it resists changes in motion induced by forces. In the presence of the gravity force, in which the resulting acceleration is resisted by something solid (the ground, a floor in a building), the matter takes on the property of weight. Weight is a manifestation of force in the particular case when the force is gravity. According to Newton's Second Law of Motion, the force law, force is defined to be mass times acceleration; that is, $F = ma$. In the case of gravity, we use g as the symbol for acceleration and W for weight and weight is seen clearly in the equation, $W = mg$.

In other words, your personal weight is the force with which earth's surface gravity acts upon your body, which itself has a mass determined by the average masses of your individual atoms and their total number. The unit of mass in the metric system is the kilogram (kg) and force in the metric system is Newtons (N). In the English system, the unit of mass is the unfamiliar slug and the unit of force is the familiar pound (lb.).

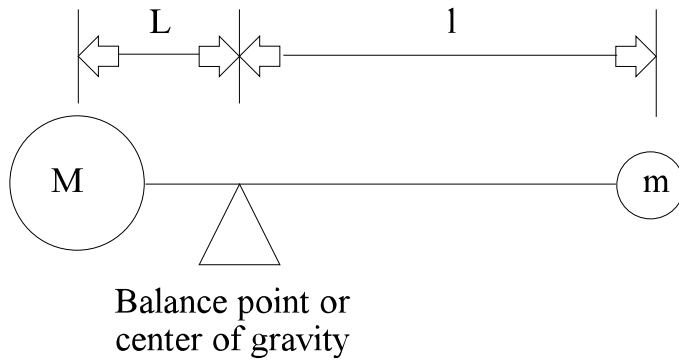
Speed is simply the distance traveled in a given time, or d/t . Velocity has two properties—speed AND direction.

5. Because according to his First Law of Motion, the Law of Inertia, moving objects go in a straight line, unless an outside force is acting on them. In that case, as much as the inertia (also though of as momentum) allows, the object will move toward the force source. Clearly, the moon orbits earth—always trying to succumb to some force from earth, but always failing to actually reach earth because of its (the moon's) inherent momentum. Momentum, incidentally, equals mv , mass times velocity.

9. Think of it as the balance point. That is, if there were a significant external gravity acting upon earth and moon, you could balance the system by suspending it at the center of gravity. The conception of the earth and moon's center of gravity is the same as that for two people on a teeter-totter (a.k.a. see-saw). In this case, think of an adult with a child. Is the balance point half-way between the adult and child (earth and moon)? Of course not. The balance point must be closer to the heavier person or object. In other words, the balance point is a result, the product, of two properties—mass and distance from the balance point. That is, $ML = ml$.

Another way of looking at this might help you, so I'll rearrange the equation above to result in a simple, inverse proportion between the mass and distance ratios:

$$\frac{M}{m} = \frac{l}{L}$$



With two people, a parent and child, their mass ratio will be something like, say, 5 to 1. The fulcrum (balance point) of the teeter-totter will therefore be one-fifth of the way from the parent to the child. For the earth-

moon system, the mass ratio is more extreme—there is 81 times more mass in the earth than in the moon! Therefore, the center of gravity is only 1/81 of the way from the center of the earth to the center of the moon. With an average separation of about 240,000 miles, this means that the center of gravity is only about 3,000 miles from the center of earth. But earth's diameter is 8,000 miles; that is to say, its radius is 4,000 miles, so you see that the center of gravity is 1,000 miles beneath the earth's surface—3/4 of the way out from the earth's center to the surface! Technically, gravitationally bound objects orbit their mutual center of gravity. In the case of the earth-moon system it can truly be said, as you learned in elementary school, that the moon orbits the earth.

Problems

1. This is a comparison problem, so Newton's Law of Gravity simplifies by cancelling out the Gravitational constant, G . (Remember that constants cancel out when taking ratios.) For that matter, you can ignore the masses involved—yours and earth's, because they don't change in the different circumstances described here, either. The only thing that changes is the distance. Looking at the relation between gravitational force with distance in Newton's gravity equation, you see that $F \propto 1/d^2$. This is the inverse-square law, which pops up in physics in several different, but related, situations. You don't necessarily need exact distances, only their ratios in these comparative situations. On Earth's surface, at distance equals one earth radius, the force is one—the comparison unit. At ten earth radii, the force is $1/10^2$ as strong or $1/100$. At 20 times farther out, the force's effect is $1/20^2$ or $1/400$ as strong as at the surface.
2. You have, or soon will, be making this exact calculation for the moon and all the other large objects of the solar system, so I'll not belabor this here.