6 A Property of Matter - Mass

Name__________________________________

Reading: MASS — NOT A WEIGHTY MATTER

AP/Inquiry Physics

You have been investigating the idea of mass. You know that the greater the mass an object has, the greater its tendency to resist motion. Imagine that you push two objects of greatly differing mass – perhaps a large boulder and a small pebble. Because the boulder has a very large mass, it will resist a change in its motion more, and your push will have little effect on it. On the other hand, the pebble can be easily moved by your push. The tendency an object has to resist a change in its motion is called **inertia**. Inertia has no units, but is directly proportional to (as well as due to) the mass of an object.

Now suppose that the boulder and the pebble are coming toward you at 60 miles/hour. Which one would be easier to stop? Since the boulder has greater mass and, therefore, greater inertia, it will be much harder to stop than the pebble. You will have to exert a much greater force to stop the massive boulder.

When a cup sits on a table, there is a pair of forces in balance. Consider the forces acting on the cup. The force due to gravity pulls downward on the cup, but the table counterbalances this force with an equal and upward force. When a car is travelling down a road at a constant speed, a different pair of forces is acting. The forces of air resistance and mechanical friction are being balanced by forces produced by the car's tires. We may conclude from these and similar examples that **only unbalanced forces accelerate objects**.

The mass of an object depends on the quantity of matter in the object, or in other words, on the number and kind of molecules which make up the object. The difference between weight and mass is most apparent when we examine an object in space. If we travel a distance above the earth's surface equal to the radius of the earth, the object will weigh only one quarter of what it weighed at the earth's surface. For example, if you weighed 160 pounds on earth, you would only weigh 40 pounds at an altitude of 4000 miles or 6440 kilometers above the earth. (The earth's radius is approximately 4000 miles.) What a marvelous way to lose weight - clearly superior to all the diets you've heard of! But what does it mean to lose weight in space? Does it imply that you've lost your arms or your legs? Don't lose your head - of course not! Weight is the force due to the earth's gravity which acts on you. It changes as you increase or decrease your distance from the center of the earth's gravitational field, which is the geographical center of the earth. But you don't add or lose any matter - your weight changes, but your mass remains the same. When would you become **weightless**?

How do we know that your weight in the previous paragraph would be only one quarter of what it was on the earth's surface? This calculation comes from the **Law of Universal Gravitation** formulated by Sir Isaac Newton. We will study this law later in the course. One of the primary predictions of this law is that the weight of an object decreases as it travels farther from the center of the earth. This is why objects at the equator weigh slightly less than they would at the poles; the earth’s spin makes it bulge around the equator.

For hundreds of years after Newton, scientists believed that while weight varied with location in a gravitational field, mass remained constant regardless of location. Are there situations under which mass does change? Albert Einstein suggested that mass was related to energy by the famous equation $E=mc^2$, where c is the velocity of light. Although we have not studied this topic in enough depth to know why, this equation predicts that as an object’s speed increases, its mass increases. This effect only becomes apparent at incredibly high speeds, much faster than we can make large objects move. We can, however, make tiny particles move at speeds near that of light (186,000 miles per second or 300 million meters per second) and his predicted increases in mass do occur. So mass remains constant and unchanging, except when it travels at speeds which are a significant fraction of light speed.

QUESTIONS   ANSWER WITH SEVERAL COMPLETE SENTENCES

1. What is an **unbalanced** force? What does an unbalanced force do to an object? (Be exact.)

2. Victor Vector weighs 650 newtons, while Velma Velocity weighs 750 N. Who has greater inertia? Describe your entire train of logic which led you to that conclusion.

3. Suppose you were in a **weightless** environment. If you looked in a mirror, would you appear any thinner? Justify your answer.

4. Under what condition did Einstein say the mass of an object would increase?

5. **Describe** a situation in which knowing the mass of an object would be preferable to knowing its weight. **Be specific and creative! Explain** your answer, and be careful not to confuse mass with volume.