3.5 Mass—A Measure of Inertia

Kick an empty tin can and it moves. Kick a can filled with sand, and it doesn't move as much. Kick a tin can filled with solid lead, and you'll hurt your foot. The lead-filled can has more inertia than the sand-filled can, which in turn has more inertia than the empty can. The can with the most matter has the greatest inertia. The amount of inertia an object has depends on its **mass**—that is, on the amount of material present in the object. The more mass an object has, the more force it takes to change its state of motion. Mass is a measure of the inertia of an object.

Fig. 3-7 You can tell how much matter is in the can when you kick it.

Mass Is Not Volume

Many people confuse mass with volume. They think that if an object has a large mass, it must have a large volume. But volume is a measure of space and is measured in units such as cubic centimeters, cubic meters, or liters. Mass is measured in **kilograms**. (A liter of milk, juice, or soda—anything that is mainly water—has a mass of about one kilogram.) How many kilograms of matter are in an object, and how much space is taken up by that object, are two different things. Which has the greater mass—a feather pillow or a common automobile battery? Clearly the more difficult to set in motion is the battery. This is evidence of the battery's greater inertia and hence greater mass. The pillow may be bigger—that is, it may have a larger volume—but it has less mass. Mass is different from volume.

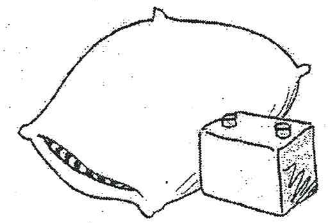

Fig. 3-8 The pillow has a larger size (volume) but a smaller mass than the battery.

Mass Is Not Weight

Mass is most often confused with weight. We say something has a lot of matter if it is heavy. That's because we are used to measuring the quantity of matter in an object by its gravitational attraction to the earth. But mass is more fundamental than weight; mass is a measure of the actual material in a body. It depends only on the number and kind of atoms that compose it. Weight is a measure of the gravitational force that acts on the material, and depends on where the object is located.

The amount of material in a particular stone is the same whether the stone is located on the earth, on the moon, or in outer space. Hence, its mass is the same in any of these locations. This could be shown by shaking the stone back and forth. The same force would be required to shake the stone with the same rhythm whether the stone was on earth, on the moon, or in a force-free region of outer space. That's because the inertia of the stone is solely a property of the stone and not its location.

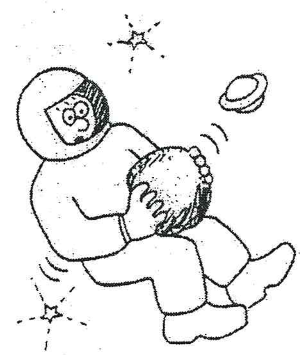

Fig. 3-9 The person in space finds it just as difficult to shake the stone in its weightless state as it is to shake it in its weighted state on earth.

But the weight of the stone would be very different on the earth and on the moon, and still different in outer space if the stone were away from strong sources of gravitation. On the surface of the moon the stone would have only one-sixth its weight on earth. This is because gravity is only one-sixth as strong on the moon as compared to on the earth. If the stone were in a gravity-free region of space, its weight would be zero. Its mass, on the other hand, would not be zero. Mass is different from weight.

We can define mass and weight as follows:

Mass: The quantity of matter in a body. More specifically, it is a measure of the inertia or "laziness" that a body exhibits in response to any effort made to start it, stop it, or change in any way its state of motion.

Weight: The force due to gravity upon a body.

Mass and weight are not the same thing, but they are proportional to each other. Objects with great masses have great weights. Objects with small masses have small weights. In the same location, twice as much mass weighs twice as much. Mass and weight are proportional to each other but not equal to each other. Mass has to do with the amount of matter in the object. Weight has to do with how strongly that matter is attracted by the earth's gravity.

▸ Questions

1. Does a 2-kilogram iron block have twice as much *inertia* as a 1-kilogram block of iron? Twice as much *mass*? Twice as much *volume*? Twice as much *weight* (when weighed in the same location)?
2. Does a 2-kilogram bunch of bananas have twice as much *inertia* as a 1-kilogram loaf of bread? Twice as much *mass*? Twice as much *volume*? Twice as much *weight* (when weighed in the same location)?

▸ Answers

1. The answer is yes to all questions. A 2-kilogram block of iron has twice as many iron atoms, and therefore twice the amount of matter, mass, and weight. The blocks are made of the same material, so the 2-kilogram block also has twice the volume.
2. Two kilograms of *anything* has twice the inertia and twice the mass of one kilogram of anything else. In the same location, two kilograms of anything will weigh twice as much as one kilogram of anything (mass and weight are proportional). So the answer to all questions is yes, except for volume. Volume and mass are proportional only when the materials are the same, or when they are equally compact for their mass—when they have the same *density*. Bananas are denser than bread—enough so that two kilograms of bananas have less volume than one kilogram of ordinary bread.