7.1: Gravity on Earth

? What Do You Think: Speed of Falling Objects

We all know that we are held to the ground (or floor or our chair) by some physical effect. We can jump off the ground, but we do not rise very far before we reverse direction and fall back down again. We also know that if we step off a high cliff, we will fall. Our downward speed will increase as we fall until some object obstructs our motion. Why is this the case?

People have long wondered why we are joined to the ground, seemingly by an invisible chain. The Greek thinker Aristotle offered the hypothesis that heavy objects fall faster than light objects, and that both fall down because it is natural for them to do so. While this hypothesis seems plausible, it does not explain why objects fall down. Galileo Galilei, the Italian astronomer and physicist, conducted laboratory experiments that showed that all objects under the influence of gravity fall toward the ground at the same rate. His result disproved our intuitive sense of how gravity affects objects: many of us, more than 400 years after Galileo's experiments, tend to think that heavy objects fall faster than light ones do, just as Aristotle did. In fact, they do not, at least not when the effects of friction can be ignored.

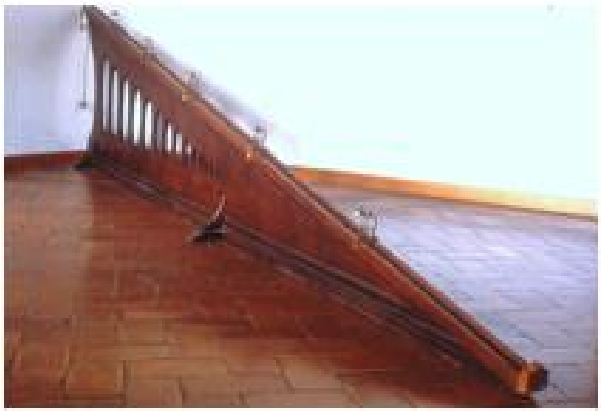

Figure 7.1: Galileo's Experimental Apparatus. Galileo used experiments based upon systems similar to this one to study the motion of falling objects. He also studied the motions of pendula, finding that their periods depend only upon their length, not upon the mass of the object suspended. Credit: Museo Galileo, Florence - Photo Franca Principe

Contrary to some popular ideas, Galileo did not study gravity solely by dropping objects from the Leaning Tower of Pisa. He was indeed a professor in that city at the time he conducted his gravity experiments, but he devised more accurate experiments. These included rolling balls of different sizes and weights down inclined tracks (like in figure 7.1), and studying the motions of pendula to which he had attached bobs of different masses and strings of different lengths. Galileo's experiments were not trivial because the speed of rolling objects is affected not only by their mass, per se, but by how that mass is distributed. Two balls of identical weight but different diameters will not roll down a hill with the same speed. Galileo was able to account for this effect.

What Galileo found was that all objects, regardless of their weight, fall under the influence of gravity at a speed that increases by about 9.8 meters per second every second. He did not express his values in terms of meters and seconds, of course. His results mean that if an object starts from rest, after one second it will be moving 9.8 m/s. Then, after another second it will be moving at 19.6 m/s, after another second it will be moving 29.4 m/s, and so on. The increase in the speed of a falling object is called the gravitational acceleration, or sometimes it is called one *g*. Galileo had no idea why things fall toward the ground, nor why they all fall at the same rate. He merely conducted an experiment, and that was his result.

How Fast Do Objects Fall?

Worked Example:

1. Consider what would happen if we dropped a massive textbook from the top of a very tall building. Assume the textbook mass is 5 kg.

How fast would the textbook be falling after 5 seconds?

- Given: acceleration due to the Earth's gravity $g = 9.8\ m/s^2$, t = 5 sec
- Find: *v*, the textbook's velocity
- Solution: The textbook starts at rest, that is, with an initial velocity of zero. Once you drop it, the textbook falls 9.8 m/s faster every second. So after 5 seconds, the textbook's velocity = (5 s)(9.8 m/s^2) = 49 m/s. Note: the mass of the textbook did not enter into this calculation.

Questions

For more examples, see Math Exploration 7.1.

Math Exploration 7.1

Gravity on the Moon

VIEW TRANSCRIPT

In the video, you should have seen that both the hammer and feather reached the ground at the same time, consistent with Galileo's findings. On the Moon, gravity is the only force acting on the objects. In the next section, we will take a closer look at how objects' motions are affected when more than one force acts on them.