6.1 NEWTON'S FIRST LAW OF MOTION

Before Galileo Galilei (1564-1642), people generally believed that a continuous push was necessary to maintain the motion of an object, although some philosophers had suggested otherwise. From his experiments Galileo convincingly showed that

"A body moving on a level surface will continue in the same direction at constant speed unless disturbed".

It is easy to demonstrate this fact of nature by the simple experiment shown in Fig. 6.1. Suppose you take two inclined surfaces and roll a marble from some fixed place on one incline, and observe what happens on the second plane. If the surfaces are hard and the ball rolls without sliding, you will find that the ball reaches approximately the same height on the second plane. Now, notice what happens as you reduce the angle of the incline of the second inclined surface. The same height on the second incline now appears at a longer distance from the base. Galileo concluded that, if the second incline was a truly horizontal surface, then the ball will continue to travel at a constant speed indefinitely on the horizontal track.

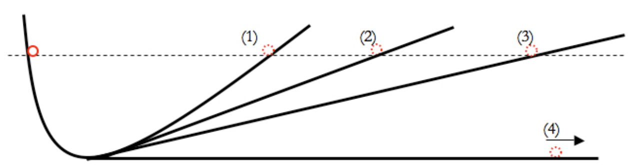

Figure 6.1: A ball is rolled on an inclined plane and allowed to continue on a second inclined plane. The ball reaches approximately the same height regardless of the angle of incline of the second surface. With less angle of incline, the ball goes farther, and in the limit of zero degree incline, i.e. a horizontal surface, the ball would continue for ever in a straight line with a constant speed.

Isaac Newton generalized Galileo's conclusions and enunciated his **first law** in *Principia* as follows.

"Every body preserves in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon".

The reason for continuation of uniform motion of a body is not known. The tendency of material bodies for preserving their state of rest or of motion is called **inertia**. In *Principia* Newton included the following definition of this innate tendency of all bodies and called it inertia.

"The *vis insita*, or innate force of matter, is a power of resisting, by which every body, as much as in it lies, endeavors to preserve in it present state, whether it be of rest, or of moving uniformly forward in a right line".

Newton went on to further explain the nature of this so-called innate force.

"This force is ever proportional to the body whose force it is; and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inactivity of matter, is not without difficulty put out of its state of rest or motion. Upon which account, this *vis insita*, may, by a most significant name, be called *vis inertia*, or force of inactivity. But a body exerts this force only, when another force, impressed upon it, endeavors to change its condition; and the exercise of this force may be considered both as resistance and impulse; it is resistance, in so far as the body, for maintaining its present state, withstands the force impressed; it is impulse, in so far as the body, by not easily giving way to the impressed force of another, endeavors to change the state of the other. Resistance is usually ascribed to bodies at rest, and impulse to those in motion; but motion and rest, as commonly conceived, are only relatively distinguished; nor are those bodies always truly at rest, which commonly are taken to be so. "

Unlike Newton, physicists now do not believe on any innate force as the reason for inertia. Instead, the first law of motion is understood to highlight the role of special frames of observation.

Role of the frame of observation

The tendency to maintain inertia is evident only if the motion is observed from particular types of reference frames, called **inertial frames**, which are themselves defined as frames of those observers who would observe this tendency. Thus, the definition of inertial frames only restates what is meant by inertia in a more operational sense.

For instance, if you were to observe a tree from the roadside, yourself at rest with respect to the road. Then, you would find that the tree is at rest with respect to you, which is no surprise at all.

However, if you were to look at the same tree from inside an accelerating car, the tree will appear to move with acceleration in the other direction to the car's acceleration, even when there is no net force on the tree. In this frame, the tree appear to acquire acceleration without any impressed force. Therefore, the observation from inside an accelerating car violates Newton's first law of motion.

How about an observation from inside a car that is moving at a constant velocity with respect to the road? This observer will assign a constant velocity to the tree in the other direction to the car's velocity with respect to the road. The observer will now say that the tree is moving with a constant velocity and has no net force on it. This observation agrees with the first law of motion.

Thus, we see that two observers, one at rest with respect to the road and the other at constant velocity with respect to the road, agree with the observation of Galileo that no force on the object would correspond to no change in velocity. But, the other observer, the one accelerating with respect to the road, does not agree with this conclusion. The observers with respect to whom the law of inertial is obeyed are called inertial observers. We state the first law of motion as a requirement of existence of these special frames in nature.

There exist reference frames in nature, called inertial frames, such that, when observed from these frames, an object will have no acceleration if there is no net force on the object.

Supposing that the center of the universe is at rest, then any frame that is at rest with respect to this center or moving at constant velocity with respect to this center will be an inertial frame. A frame fixed to earth is actually rotating and is not an inertial frame. But, for many practical purposes, we find that the non-inertiality of a frame fixed to the Earth does not make significant impact. Therefore, we will assume that an earth-based frame is an inertial frame until we discuss physics in non-inertial frames in a later chapter. There, you will study the phenomena in which the non-inertiality of earth-based frames plays a crucial role, and must be taken into account for properly making sense of the observations made by earth-based observers.