Two Simple Forms of Motion

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Newton's First Law of Motion is: "Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it." Translated into somewhat more modern language, the Law states that a mass does not accelerate unless a force acts on it. More specifically, a mass moves in a straight line at a constant speed unless a force acts on it.

Newton's Second Law of Motion is that a particle accelerates at a rate proportional to the force acting on it, and inversely proportional to the mass of the particle. In equation form,

$$m\frac{D\mathbf{V}}{Dt} = \mathbf{F} .$$

(1)

Here m is the mass of the particle, $\frac{D\mathbf{V}}{Dt}$ is the acceleration of the particle, and $\mathbf{F}$ is a force vector. Although (1) is a statement of Newton's Second Law of Motion, it is consistent with his First Law of Motion, because if we set the force vector on the right-hand side of (1) to zero, we find that there is no acceleration, which means that the mass "moves in a straight line at a constant speed." The Second Law of Motion thus implies the First Law of Motion.

Motion in a straight line at constant speed is undeniably a simple form of motion. A second simple form of motion is rotation. Consider a ball spinning in the absence of external forces. Each particle of the ball moves along a circular path; this is what we mean when we say that the particles of the ball are rotating. The molecular forces that hold the material of the ball together prevent the particles from moving in a straight line at constant speed, and cause them to move along circular paths instead. *The molecular forces are perpendicular to the motion of each particle, so that.*

$$\mathbf{F} \cdot \mathbf{V} = 0 .$$

(2)

A force that is perpendicular to the motion of a particle does no work on the particle. Use of (2) in (1) gives

$$\frac{D}{Dt}\left(m\frac{\mathbf{V} \cdot \mathbf{V}}{2} \right) = 0 ,$$

(3)

where we have assumed that $\frac{Dm}{Dt} = 0$, i.e., that the mass of the particle does not change as it moves. Since no work is done, no energy supply is needed, and the kinetic energy of the particle does not change with time. Rotation will continue forever in the absence of external forces such as friction.

Because rotation can continue forever in the absence of external forces, rotational motion is almost as simple as motion in a straight line at constant speed. I say "almost" because rotational motion requires a force, while motion in a straight line at constant speed occurs in the absence of forces.