

## 17.1: Introduction to Two-Dimensional Rotational Dynamics

**torque, n. a.**

*The twisting or rotary force in a piece of mechanism (as a measurable quantity); the moment of a system of forces producing rotation.*

Oxford English Dictionary

A body is called a rigid body if the distance between any two points in the body does not change in time. Rigid bodies, unlike point masses, can have forces applied at different points in the body. For most objects, treating as a rigid body is an idealization, but a very good one. In addition to forces applied at points, forces may be distributed over the entire body. Forces that are distributed over a body are difficult to analyze; however, for example, we regularly experience the effect of the gravitational force on bodies. Based on our experience observing the effect of the gravitational force on rigid bodies, we shall demonstrate that the gravitational force can be concentrated at a point in the rigid body called the center of gravity, which for small bodies (so that  $\vec{g}$  may be taken as constant within the body) is identical to the center of mass of the body.

Let's consider a rigid rod thrown in the air (Figure 17.1) so that the rod is spinning as its center of mass moves with velocity  $\vec{V}_{\text{cm}}$ . We have explored the physics of translational motion; now, we wish to investigate the properties of rotational motion exhibited in the rod's motion, beginning with the notion that every particle is rotating about the center of mass with the same angular (rotational) velocity.

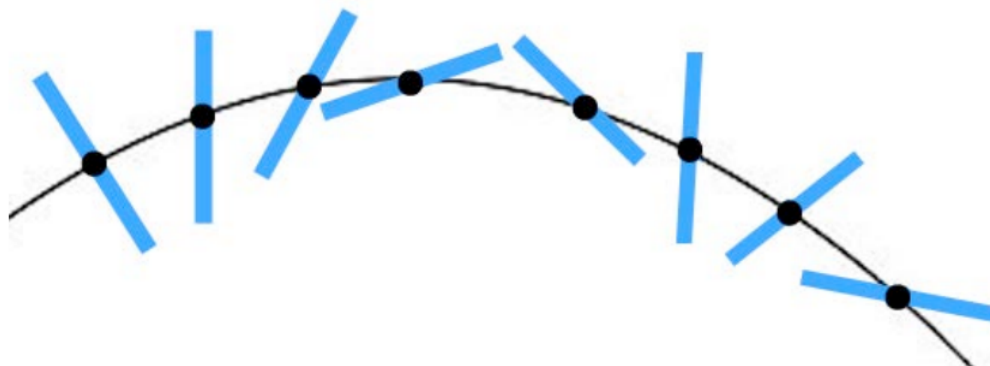


Figure 17.1 The center of mass of a thrown rigid rod follows a parabolic trajectory while the rod rotates about the center of mass.

We can use Newton's Second Law to predict how the center of mass will move. Because the only external force on the rod is the gravitational force (neglecting the action of air resistance), the center of mass of the body will move in a parabolic trajectory.

How was the rod induced to rotate? In order to spin the rod, we applied a torque with our fingers and wrist to one end of the rod as the rod was released. The applied torque is proportional to the angular acceleration. The constant of proportionality is the moment of inertia. When external forces and torques are present, the motion of a rigid body can be extremely complicated while it is translating and rotating in space.

In order to describe the relationship between torque, moment of inertia, and angular acceleration, we will introduce a new vector operation called the vector product also known as the "cross product" that takes any two vectors and generates a new vector. The vector product is a type of "multiplication" law that turns our vector space (law for addition of vectors) into a vector algebra (a vector algebra is a vector space with an additional rule for multiplication of vectors).

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