Center of Mass

Unit: Rotational Dynamics

NGSS Standards: HS-PS2-1


AP Physics 1 Learning Objectives: 4.A.1.1

Knowledge/Understanding Goals:
- center of mass

Skills:
- find the center of mass of an object

Language Objectives:
- Understand and correctly use the term “center of mass.”
- Accurately describe and apply the concepts described in this section using appropriate academic language.

Labs, Activities & Demonstrations:
- Spin a hammer or drill team rifle.

Notes:

Center of mass: the point where all of an object’s mass could be placed without changing the overall forces on the object or its rotational inertia.
Objects have nonzero volumes. For any object, some of the mass of the object will always be closer to the center of rotation, and some of the mass will always be farther away. In most of the problems that you will see in this course, we can simplify the problem by pretending that all of the mass of the object is at a single point.

You can find the location of the center of mass of an object from the following formula:

\[ r_{cm} = \frac{\sum_{i=1}^{n} m_i r_i}{\sum_{i=1}^{n} m_i} \]

In this equation, the symbol \( \sum \) means “summation.” When this symbol appears in a math equation, calculate the equation to the right of the symbol for each set of values, then add them up.

In this case, for each object (designated by a subscript), first multiply \( mr \) for that object, and then add up each of these products to get the numerator. Add up the masses to get the denominator. Then divide.

Use this space for summary and/or additional notes.
Because an object at rest remains at rest, this means that an object’s center of mass is also the point at which the object will balance on a sharp point. (Actually, because gravity is involved, the object balances because the torques cancel. We will discuss that in detail later.)

Finally, note that an object that is rotating freely in space will always rotate about its center of mass:

Use this space for summary and/or additional notes.
Sample Problem:
Q: Two people sit at the ends of a massless 3.5 m long seesaw. One person has a mass of 59 kg, and the other has a mass of 71 kg. Where is their center of mass?

A: (Yes, there’s no such thing as a massless seesaw. This is an idealization to make the problem easy to solve.)

In order to make this problem simple, let us place the 59-kg person at a distance of zero.

$$r_{cm} = \frac{\sum m_{i}r_{i}}{\sum m_{i}}$$

$$r_{cm} = \frac{(59)(0) + (71)(3.5)}{(59 + 71)}$$

$$r_{cm} = \frac{248.5}{130} = 1.91 \text{ m}$$

Their center of mass is 1.91 m away from the 59-kg person.