LINEAR MOMENTUM AND COLLISIONS

KEY TERMS

Term (symbol)	Meaning
Linear momentum (p)	Product of an object's mass and velocity. Also called "momentum" for short. Momentum is conserved when no external forces act on a system. Vector quantity with SI units of $\frac{\mathrm{kg} \cdot \mathrm{m}}{\mathrm{s}}$.

Equations

Equation	Symbols	Meaning in words
$p = mv$	p is momentum, m is mass, and v is velocity	Momentum is mass times velocity.
$\Delta p = F_{\mathrm{net}} \Delta t$	F_{net} is the net external force, Δp is change in momentum, and Δt is the time over which a net force acts	Change in momentum is proportional to the net external force and the time over which a net force acts.

How momentum and net force are related

You might recall from the kinematic equations with constant acceleration that change in velocity Δv can also be written as $a\Delta t$. We can then see that any change in momentum following an acceleration can be written as

$$\begin{aligned}\Delta p &= m\Delta v \\ &= m(a\Delta t) \\ &= F_{\text{net}}\Delta t\end{aligned}$$

If we rearrange this to solve for F_{net} when the mass of the system and net force is constant, we get Newton's second law

$$F_{\text{net}} = \frac{\Delta p}{\Delta t}$$

Thus, the change in momentum over time is equal to the net force.

A bigger net force over the same time period means a larger change in momentum. For example, a heavy truck coming to a stop will have a much larger change in momentum than a light car in the same amount of time. A larger change in momentum means a larger external force is needed to slow it down, so the truck brakes have to work much harder!

Common mistakes and misconceptions

1. **Some people think momentum and kinetic energy are the same.** They are both related to an object's velocity (or speed) and mass, but momentum is a vector quantity that describes the amount of mass in motion. Kinetic energy is a measure of an object's energy from motion, and is a scalar.
2. **Sometimes people think momentum is the same as force.** Forces cause a change in momentum, but momentum does not cause a force. The bigger the change in momentum, the more force you need to apply to get that change in momentum.