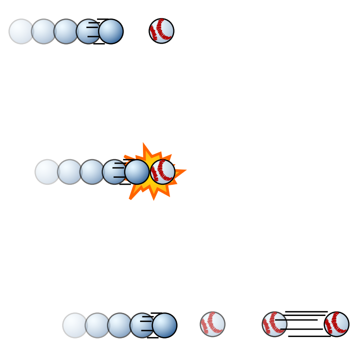
The rate of change of an object's momentum equals the overall rate at which momentum is received from other objects

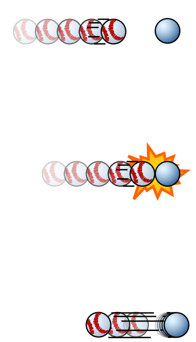
Mass

We can use collisions to distinguish objects. Objects can differ in the amounts by which their velocities are altered and by which they alter other objects' velocities. We assign each object participating in a collision a **mass to quantify** this distinction.

Launch shot put ball at softball



Launch softball at shot put ball

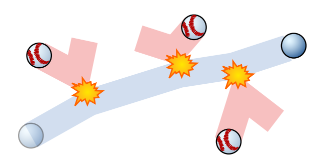


$$m$$

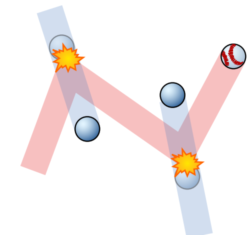
Momentum

The mass that characterizes how an object participates in one collision also characterizes how that object participates in future and past collisions.

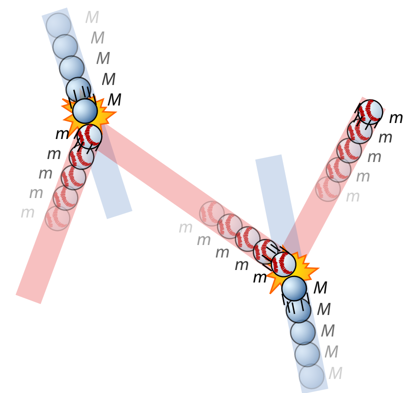
Collision after collision, shot put ball trajectory remains mostly undisturbed



Collision after collision, softball trajectory is repeatedly dramatically altered



We attach the label and concept of mass to individual objects at each instant in time as though mass were an intrinsic, constant, and local property belonging to atomistic objects.

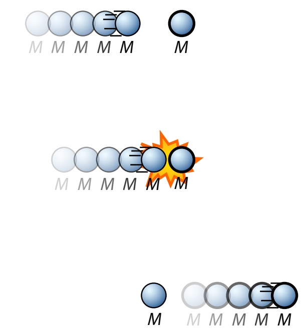


We hypothesize that an object's state of motion can be understood by considering both how much mass is moving and how quickly (and in what direction) that mass is moving. **Momentum** quantifies this concept.

$$\mathbf{p} = m\mathbf{v}$$

Momentum transfer

An object can transfer momentum to another object.



$$\Delta\mathbf{p}_1 = -\Delta\mathbf{p}_2$$

Force

An object can accrue a change in momentum over time. The portion of the time-rate of change of momentum owing to a particular interaction source is called a force (e.g. repeated collisions with a surface can provide a "normal" force and repeated collisions with air molecules can provide a "drag" force).

$$\mathbf{F}_{1\text{ ON }2} = \frac{\Delta\mathbf{p}_{\text{FROM 1 TO 2}}}{\Delta t}$$

The sum of forces on an object is the overall rate of change of momentum of that object.

$$\sum \mathbf{F}_{i\text{ ON }2} = \frac{\Delta\mathbf{p}_2}{\Delta t}$$