# Introduction

In this ILD, we’ll figure out exactly where the equation expressing conservation of momentum comes from and how it relates to other physics concepts.

## First, let’s make sure we agree about what conservation of momentum says. Two students are arguing about this, talking about a collision between object 1 and object 2:

LINDA: Conservation of momentum says that the total momentum of the system before the collision equals the total momentum of the system after the collision:

*m*1**v**1 before + *m*2**v**2 before = *m*1**v**1 after + *m*2**v**2 after

JENNIFER: No, I think conservation of momentum says that, in the collision, the momentum gained by one object equals the momentum lost by the other:

*m*1 ∆**v**1 = –*m*2∆**v**2.

The minus sign says that the *gain* in object 1’s momentum equals the *loss* in object 2’s momentum, or vice versa; one compensates for the other.

Which student or students do you agree with?

(i) I agree with Linda.

(ii) I agree with Jennifer.

(iii) I agree with both: They’re saying the same thing in different ways.

(iv) I agree with both, though they disagree with each other.

(v) I agree with neither.

✯ *Rad polling. Class discussion: Are the equations the same?*

## Where do you think conservation of momentum comes from?

(i) Momentum conservation is just another way of writing Newton’s laws. So, this isn’t really a new topic at all.

(ii) The whole point of momentum conservation is that it gives us a way to think about what happens during a collision even when we *don’t* know the size of the forces involved. So, momentum conservation is a new topic, based on new concepts, only loosely connected to forces and the like.

(iii) I’m torn; I kind of agree with elements of both (i) and (ii).

✯ *Rad polling. Class discussion*

# Deriving momentum conservation

Let’s play the implications game, applying Newton’s 2nd and 3rd laws to a collision between objects 1 and 2, and see where that leads us.

 As we saw with the truck-and-car scenario, Newton’s’ 3rd law says that objects 1 and 2 exert equally strong forces on each other, though in opposite directions:

*F*2 on 1 = – *F*1 on 2

## (*Work together*) Suppose that, during the collision, the forces exerted by the objects on each other are the *net forces* felt by each object. Use Newton’s 2nd law (*F*net = *ma*) to rewrite the gray-shaded equation in terms of the mass and accelerations of the objects during the collision (*m*1, *a*1, *m*2,and *a*2).

## (*Work together*) Now use the basic definition of acceleration to rewrite that equation in terms of the masses (*m*1 and *m*2,), the changes in velocity of each object during the collision (∆*v*1 and∆*v*2), and the time interval over which the collision occurs (∆*t*).

## (*Work together*) Now multiply through by ∆*t*. Does the result look familiar?

## (*Work together*) Before coming to lecture, you already knew that momentum is conserved. So what was the point of the mathematical steps we led you through in parts A through C?

## (*Work together*) Based on the derivation you just did, state a general rule about when momentum is conserved and when it isn’t. Hint: In parts A through C, what assumption or assumptions did you make *besides* Newton’s laws?

✯ *Class discussion*

# Applying momentum conservation

velocity

time

collision

(*Work together*) A cart of mass 1 kg, rolling along a level track with negligible friction, collides with a stationary second cart of mass 2 kg. Due to Velcro, the carts stick together and move as a single unit after the collision. We’ve sketched the first few moments of the 1 kg cart’s velocity vs. time. Complete the graph, being as exact as possible.

✯ *Class discussion. Experiment.*