Let's examine when the momentum of a system is constant, and apply that to solving problems.

First, we'll revisit the impulse equation.

On the left, we have the impulse, the integral of the total external force acting on a system between some initial and final times.

And on the right, we have the change in the total momentum of the system, between those initial and final times.

In a situation where the impulse is 0, we have that the change in the momentum is 0.

P initial is equal to p final.

In other words, the momentum of the system is constant between some initial and final time.

This is a vector equation.

But in many problems, we can set up our coordinate system so we only have to consider one dimension.

Here's a simple example of one block moving along a horizontal surface with some initial velocity, colliding with a block at rest.

And then the two blocks stick together and move.

Is momentum constant during this collision?

To answer that question, we need to think about what our system is.

Let's look at the system of both blocks together.

We can see the external forces, gravity and the normal force, add up to 0.

So our total external force is 0.

During the collision, each block exerts a force on the other.

But that is an internal force if both blocks are included in our system.

You can see that if our system was just one of the two blocks, we would need to know the collision force in order to solve for the final speed.

Therefore, we will choose our system to be the two blocks together.

We then need to set up a coordinate system.

We'll pick the origin here, and this direction to be positive x.

Now we need to identify the initial and final states.

Our initial state will be just before the blocks collide.

The momentum of the system is the sum of the momentum of each block individually.

We have m1 times v1 initial x times i-hat plus m2 times v2 initial x times i-hat.

This second term is 0, since block 2 starts at rest.

The final state is right after the collision when the two blocks are moving together.

They have the same velocity, so the final momentum is m1 plus m2 times v final x times i-hat.

This gives us an equation that will allow us to solve for whatever quantity we are not given.

Now let's look at a similar collision, one that's happening in two dimensions.

If we have one block coming up from the bottom, hitting one that's coming in from the side, I'll choose my unit vectors to be like this, my origin here.

The momentum equation gives us two equations, one along the x direction and the other along the y direction.

Once again I'll choose the initial state to be just before the collision and the final state to be just after the collision.

The momentum in the initial state is again the sum of the momentum of each block individually.

And the momentum in the final state is the mass of the two blocks added together times the velocity of the two blocks.

Notice that this velocity has a component in both the x and the y directions.

Again the total external force on the system is 0.

So the impulse is 0 in both the x and y directions, and therefore, momentum is conserved for both the x and y components.

So I can write my two momentum equations like this.

The impulse equation is a vector equation.

So generically, in two dimensions, we will have two equations.

We always need to check that the momentum is conserved in each direction separately.

And it is possible to have a case where momentum is conserved in one direction but not the other, if we have some net external force in one direction.

What would happen if, in our 1d collision example, the blocks now experienced friction along the surface?

Can we still assume that the momentum is conserved?

In fact, if we pick a point in time right before the collision and compare that to a point in time right after the collision, we can see that the impulse from friction is over such a short period of time, that the impulse is really small.

And we can say that the momentum is approximately constant.

If we consider times later, after the collision is over, then momentum is certainly not conserved, which is what you would expect.

You'll see the two blocks slow down due to friction.

So even if there are other forces acting on the system, like friction or gravity, we can still calculate the result of a collision as if the momentum is constant during the collision by picking times only a very small delta t apart.