Impulse and Momentum

Overview: Any object that is moving has momentum. Momentum is the product of the mass and the velocity. Larger and heavier objects will have a higher momentum than lighter and smaller objects.

What to Learn: You'll discover how to describe the velocity describe of an object by specifying both direction and speed as well as calculate momentum.

Materials

- handful of coins (at least two of each)
- pillow
- wall
- wagon
- skateboard

Lab Time

1. Find a wall.
2. Hit it with your bare fist. (Take it easy! Just hit it with enough force that you feel the impact *lightly*.)
3. Now put a pillow in front of the wall and hit it with about the same force as you hit it before.
4. With the pillow in front of the wall, you can hit it a little harder if you like, but again, don't go nuts!

What did the pillow do? It slowed the time of impact. Remember our formula Ft=mv. When the momentum of your moving fist struck the wall directly, the momentum was cut to zero instantly and so you felt enough force to hurt a bit. When the pillow was in the way, it took longer for your momentum to come to zero. So you could hit the pillow fairly hard without feeling much force. Basically a bike helmet is like a pillow for your head. It slows the time of impact, so when you fall off your bike, there is much less force on your head. Just be glad your mom doesn't make you wear a pillow on your head!

So let's go back to momentum for a minute. Momentum is inertia in motion. It is how much force it takes to get something to slow down or change direction. One more concept I'd like to give you is conservation of momentum. This is basically momentum equals momentum, or mathematically mv=mv. (Momentum is mass times velocity.) When objects collide, the momentum that both objects have after the collision is equal to the amount of momentum the objects had before the collision. Let's take a look at this with this next part of the experiment.

5. Put one penny on the table.
6. Put another penny on the table about 6 inches away from the first one.
7. Now, slide one penny fairly fast towards the first penny.
8. What you want to have happen, is that the moving penny strikes (or gives impulse to) the stationary penny head on. The moving penny should stop and the stationary penny will move.
9. Now, try that with other coins. Make big ones hit small ones and vice versa. It's also fun to put a line of 5 coins all touching one another. Then strike the end of the line with a moving penny.
10. Complete the data table for this part of the experiment after you read over the information below:

This is conservation of momentum. If you were able to strike the penny head on, you should have seen that the penny that was moving stopped, and the penny that was stationary moved with about the same speed of the original moving penny. Conservation of momentum is mv = mv. Once the moving penny struck the other, all the moving penny's momentum transferred to the second penny. Since the pennies weighed the same, the v (velocity) of the first penny is transferred to the second penny and the second penny moves with the same velocity as the first penny. What happens if you use a quarter and a penny? Make the quarter strike the penny. That penny should really zip! Again mv=mv. The mass of the quarter is much greater than the mass of the penny. So for momentum to be conserved, after impact, the penny had to have a much greater velocity to compensate for its lower mass.

Mathematically it would look like this (the masses are not accurate to make the math easier to see.) After collision Mass of Quarter x Velocity of Quarter = Mass of Penny x Velocity of Penny

5g x 10m/s = 1g x v

50 = 1 x v

50/1 = v

50m/s = v or 5g x 10m/s = 1g x 50 m/s

50 momentum = 50 momentum, or momentum (p) = 50 kg m/s, where *p* stands for momentum.

After the collision, the penny is moving at 50 m/s, 5 times faster than the quarter was moving because the penny is 5 times lighter than the quarter. (I know it's really only twice as light, but for this example let's pretend.)

11. Put the wagon and the skateboard close to one another.
12. Have one person sit on the skateboard while the other sits on the wagon.
13. Make sure the wheels are straight on the wagon and that the sidewalk is relatively free of stuff in the way.
14. Have one person give a good shove to the other person. Usually, it is easier for the person on the skateboard to push on the wagon. If this is true with your setup, then do it that way. Otherwise, do whatever is easiest.
15. Feel free to add more people or weight to the wagon and try it again.

Can you see how this and the one before it are really showing the same concept? Who went farther and faster? The lighter person on the lighter vehicle, right? The impulse of the push was the same for both vehicles, so both vehicles had the same momentum. Momentum is mass and velocity, so if the mass for both vehicles was the same, the speed would be the same. If the mass of one was more than the mass of the other, then the heavier one would move more slowly than the lighter one.

Impulse and Momentum Data Table

Weights of US coins: Penny= 2.5 g, Nickel = 5.0 g, Dime = 2.3 g, Quarter = 5.7 g, Half dollar = 11.3 g, Dollar = 8.1 g
Assume Velocity of Object 1 = 10 m/s

Mass 1 (m_1) *(kg)*	**Mass 2** (m_2) *(kg)*	**Momentum 1** (p_1) *(kg m/ s)*	**Velocity 2** (v_2) *(m/s)*

Reading

Momentum can be defined as inertia in motion. Something must be moving to have momentum. Momentum is how hard it is to get something to stop or to change directions. A moving train has a whole lot of momentum. A moving ping pong ball does not. You can easily stop a ping pong ball, even at high speeds. It is difficult, however, to stop a train even at low speeds.

Mathematically, momentum is mass times velocity, or Momentum = m x v.

The heavier something is and/or the faster it's moving the more momentum it has. The more momentum something has, the more force it takes to get it to change velocity and the more force it can apply if it hits something.

Now let's discuss impulse. Impulse is a measure of force and time. Remember, force is a push or a pull, right? Well, impulse is how much force is applied for how much time. Mathematically it's impulse equals force x time or Impulse = F x t**.**

Think about baseball. When you hit a baseball, do you just smack it with the bat or do you follow through with the swing? You follow through, right? Do you see how impulse relates to your baseball swing? If you follow through with your swing, the bat stays in contact with the ball for a longer period of time. This causes the ball to go farther. Follow-through is important in golf, bowling, tennis and many sports for the same reason. The longer the force is imparted, the farther and faster your ball will go.

Impulse changes momentum. If an object puts an impulse on another object, the momentum of both objects will change. If you continue to push on your stalled car, you will change the momentum of the car, right? If you are riding your bike while not paying any attention and crash into the back of a parked car, you will put an impulse on the car and you and the car's momentum will change. (As a kid, I did this pretty often. That's what you get when you ride and wonder at the same time. Believe me when I tell you that my momentum changed a lot more than the car's did!!)

In fact, there is a mathematical formula about this impulse and momentum thing. Impulse = change in momentum or Ft = change in mv. Force x time = mass x velocity. Does that sound familiar to anyone? It's awfully similar to Newton's Second Law (F=ma) isn't it? In fact it's the same thing.

F t = m v

Now if we divide both sides by "t" we get F=mv/t. Another way to say v is d/t (distance over time).

So now we have F=m(d/t)/t.

Those two "t's" together are the same as t^2 and d/t^2 is a (acceleration).

So what we have now is F=ma!

This Ft = mv is very important, in fact, it can save your life. Seat belts, air bags, crumple zones and other car safety features are based on this formula. When you want to shrink the force of impact, you want to increase the time the impact takes. This is called the collision time. The longer the collision time, the longer it takes your momentum to come to zero. Here's the math.

If you are in a 1000 kg vehicle moving at 30 km/h your momentum is 1000 x 30 or 30,000. Now, let's say you hit a brick wall so your momentum goes from 30,000 to 0 in .5 seconds.

Ft=mv so F(.5) = 30,000 so F= 60,000N! (N is for Newton which is a unit of force. It takes about 1 Newton to lift an apple so this car hits with the force of 60,000 apples! Talk about apple sauce!)

That's gonna leave a mark! Now let's say that instead of hitting a brick wall you hit a mound of hay and so the impact takes 3 seconds.

Now the formula looks like this: F(3)=30,000 or F= 10,000N.

See the difference, 60,000N versus 10,000N of force. All those safety features, seat belts, helmets, air bags, are designed to increase how long it takes your momentum to come to zero. Newton's laws to the rescue! Let's do a couple of experiments here to help this information have more impact (pun intended!).

Here are the highlights for this lab:

- Impulse is the amount of time a force is put on an object, how hard and how long something gets pushed or pulled.
- Ft = Impulse. Impulse affects the momentum of an object.
- Momentum is inertia in motion, how hard it is to get something to change directions or speed. Momentum = mv.
- Conservation of momentum; mv = mv. If something hits something else, the momentum of the objects before the collision will equal the momentum of the objects after the collision.

Exercises Answer the questions below:

1. What is momentum?

2. What is impulse?

3. What is the conservation of momentum?

Answers to Exercises: Impulse and Motion

1. What is momentum? (mass times velocity)
2. What is impulse? (forces times time)
3. What is the conservation of momentum? (this occurs when objects collide – their momentum before the collision will equal their momentum after the collision)