Elementary Momentum Script (for 2 presenters)

"N" emphasizes the Newton's laws perspective. "M" emphasizes the momentum perspective.

Overview slide on screen.

N: Welcome to our physics assembly about how things move. I'm _____ and I'm a student studying _______ at UC Irvine. (*One sentence explanation of what your major is about.)* I plan to become a teacher when I graduate from college.

M: My name is _______ and I'm also a student at UC Irvine. My major is ________ so I study about _______. I plan to be a teacher after I graduate from college too.

N: In our assembly today, you are going to learn about motion --why things move the way they do. We will teach you two different ways to think about motion. There are three famous rules of motion—we call them Newton's laws of motion—and I'm going to tell you about them during our assembly today.

M: In today's assembly, I will explain another way to think about motion that we call "momentum." We have four words from our assembly up on the screen. *Slide #2*. Please read them with me. *Mass, velocity, momentum, conservation.*

N: Mass is the easiest one to understand. Beach ball/medicine ball *Slide #3.* Mass is the amount of stuff or matter something has. This beach ball doesn't have much mass *(lift it)* but this medicine ball does *(groan as you lift).* Something with lots of mass is hard to get moving but something with little mass is easy to move. *(Demonstrate with "equal" punches to balls).*

M: Mass also matters if something is already moving. If something does not have much mass, it's easy to stop. *(Throw beach ball at N.)* If something has lots of mass, it's hard to stop. *(Throw medicine ball at N.)*

N: This idea is called Newton's 1st law of motion. If something is sitting still, it keeps sitting still unless a force, like my punch *(demonstrate on beach ball),* moves it. Especially if it has lots of mass, it keeps sitting still *(punch medicine ball).* But, if something is moving, it keeps moving in a straight line unless a force stops it. *(Throw beach ball.)*

M: When N punched the ball, she gave it a force and it started to move. When I caught the ball, I gave it a force that slowed the ball down.

N: In science, we often use math to explain things. *Point to slide #3.* We also use letters to save writing. The letter "m" stands for "mass." The beach ball doesn't have very much mass, so it has m=1. The medicine ball has lots of mass, so it has m=10.

Slide #4: velocity. N advances slide as M demonstrates.

M: Velocity is our next idea. Velocity is how fast something is moving and what direction it is going. *(Crawl while speaking)* Right now I don't have much velocity and the velocity I have is in this direction *(point). (Stand up and run while talking.)* Now I have a bigger velocity in this direction *(point). (Walk back the opposite way.)* Now I have a medium velocity but it points in the other direction.

N: *(Pointing at slide with all three examples.)* In math, we use the letter "v" to stand for "velocity." We also use arrows to show a picture of how big the velocity is. This arrow means "slow velocity to the right;" we can call it v=1. This arrow means "fast velocity to the right;" we can call it v=5. This arrow means "medium arrow to the left;" we call it v=-3.

M: Now I can tell you about momentum. Momentum is mass in motion, mass that has velocity. *(Point at stationary beach ball.)* This beach ball has no momentum: It has hardly any mass and no velocity. This medicine ball has lots of momentum: It has a big mass and a big velocity. *(Throw medicine ball at N.)*

Momentum slide.

N: This slide shows a scientific math problem. To figure out the momentum, we multiply the mass times the velocity. Let's say that our mass m=1 and our velocity v=2. What is the momentum? Yell out the answer if you know what one times two is. *(Kids answer.)* That's right, one times two equals two. We use the letter "p" to stand for momentum. We can also use an arrow to show how big the momentum is: On this slide it's the red arrow.

M: *(Advance to second momentum problem.)* Here is another science math problem. If the velocity is 5 and the mass is 1, how big is the momentum? Everyone yell out your answer on the count of three. *(Kids yell answer.)* The correct answer is 5 because 1 times 5 equals 5.

N: *(Advance to third momentum problem.)* In this third science math problem, the velocity is 2 but the mass is big, m=10. What is the momentum of the big medicine ball? Everyone yell out your answer on the count of three. *(Kids yell answer.)* The correct answer is 20 because 10 times 2 equals 20. Look at the big red arrow for the heavy medicine ball.

Note: You may ask the audience if they have learned about negative numbers. If they haven't, skip the problem, but point out that the arrow points the other way.

M: *(fourth momentum problem)* Here is our last science math problem about momentum. Now the beach ball, with mass m=1, is going to the left, so its velocity is v=-5. What is the momentum now? It is minus 5 and the red arrow points in the opposite direction.

One car on air track.

N: When I turn on the air, this car will float along this track. When it is moving, it has momentum. *(Glide car down track.)* Newton's second law of motion says that you can change the momentum of something when you push or pull on it with a force. *(Stop car.)* When I push on the car, I give it a force & that changes its momentum. That's Newton 2nd law of motion. When the car runs into the bumper at the end of the track, the rubber band *(point)* pushes on the car and changes its momentum from this way *(point)* to that way *(point).*

Conservation slide.

M: This is our last idea before we show you lots of fun experiments. Do you remember this word? Can you say it with me? *(Kids read conservation.)* If you conserve something, it means that you don't waste it. In science, something that is conserved is never lost or disappears—it always stays the same. One law of motion is that a group of objects that are all by themselves will always conserve their momentum. Even if they crash into each other, the total momentum of the group will stay the same.

Two cars on track.

N: Now I have two cars. They both have the same mass. One car is sitting still. How big is its momentum? Yell out your answer. *(Kids yell.)* That's right; it is zero because it has no velocity. Now I'm going to glide this other car down the track and the two cars will bounce off of each other. Let's see what happens. *(Do it.)* The first car stopped but the second car glided off with the same velocity that the first car had.

Elastic collision slide—before collision

M: I am going to explain why this happens. Before the collision, the first car had velocity v=2 and mass m=1, so it had momentum of one times two equals two. The second car had velocity zero, so its momentum was zero. If we add up all of the momentum of the whole group, the total momentum before the collision was 2+0=2.

Elastic collision slide, including "after" collision

M: After the collision, the first car stopped. How big was its momentum? *(Zero.)* It had no momentum because its velocity was zero. The second car moved off with velocity two, so its momentum was 1x2=2. The total momentum for the system was 2, just like it was when it started.

N: That is conservation of momentum. It also works if the first car is going faster. *(Demonstrate.)*

M: The momentum before and after the collision is still the same. That is conservation of momentum.

Two cars that stick together.

N: Now let's do a different experiment. This time the cars are going to stick together when they crash. What will happen now?

M: In science, we often make a guess about what is going to happen before we do an experiment; this is called a hypothesis. I want you to show me your hypothesis for this experiment by raising your hand. The second car will start at rest. The first car will slide in with a certain velocity, like it did before. What will happen when they collide and stick together? Raise your hand if you think they will both stop. Raise your hand if you think they will both go off at the original velocity of the first car. Raise your hand if you think they'll go this way but not as fast. How many think they'll bounce back this way?

N: *Demonstrates.* I slide this one in & they both go off in the same direction but at a slower speed.

Inelastic collision 1 slide.

M: Before the collision it's like it was before. The resting car has zero momentum, the moving car has some momentum—let's call it 10. The total momentum is 10+0=10. But now, after the collision, the two cars stick together and act like one big car. Their combined mass becomes 1+1=2. Now we know that the total momentum is conserved—it stays the same. So the total momentum after they crash is still 10. For a mass of 2, what speed gives a total momentum of 10? Do you know what the velocity is after the collision? Yell out your answer. *(kids yell).* The new velocity is 5, half of what it was before.

N: This time I'm going to slide them toward each other with the same speed but they'll be coming from opposite directions. What's going to happen this time? *(Demonstrate.)* They both stop!

Inelastic collision 2 slide.

M: This time the first car has momentum just like it did before. What is different is the other car. It has the same momentum but in the opposite direction. *(Note: explain this as subtraction for a young audience.)* So we give its momentum a negative sign. When we add these momenta to find the total momentum, they subtract from each other: the total momentum is zero. Since the momentum is conserved, the total momentum is unchanged when the cars crash and stick together. So they both stop and the momentum is zero.

Kids on carts.

N: I'd like the children we chose earlier to come up. This time we are going to do the same experiment but with these children. What are your names? ____ & _____ are going to sit in these two cars. *(Seat children.)*

M: How much momentum does ____ have right now, when he is sitting still? *(Kids answer.)* How much momentum does ___ have? *(Kids answer.)* What is the total momentum of the system? That's right, 0+0=0. How much momentum will the total system have after they crash? *(Kids answer.)* They will still have zero momentum, because the total momentum of the system will not change.

N: That's right but, before we do the experiment, I want to explain a different way to think about it. Newton's third law is that forces always come in pairs. If I push M—give her a force—she pushes back with an equal and opposite force *(push each other).* If M doesn't push back *(M avoids push),* I can't give her a force and she doesn't give me one back. Forces always come in action-reaction pairs.

M: A force can be a push or a pull. These cars are going to crash into each other when ___ & ____ pull on this rope. If only ____ pulls, will anything happen? *(demonstrate with only the first kid pulling on the rope)* No, nothing happens. They both need to pull to make forces that change their momenta.

N: OK, let's do the experiment. Are you ready to pull hard and fast, ___ & ____? On your mark, get set, go!

M: What was their momentum after the crash? Zero, right. That's because the total momentum was zero before the crash and momentum is conserved.

N: By Newton's 3rd law, they pulled on each other with equal & opposite forces. That gave them momentum. When they crashed, they pushed back on each other with equal & opposite forces that stopped their momentum.

M: Hey, look at these cans! Both sides are smashed!

N: That's because the forces were equal & opposite. The cans on both cars got smashed.

M: Let's have a round of applause for our volunteers. *(Volunteers return to their seats.)*

Cars with spring

M: Here is another experiment that has a similar idea. These cars are connected by springs. Right now, the two cars have equal masses. Where will the cars collide? I'll put this cone here in the middle so you can see. *(Demonstrate.)* In this case, both cars pull on each other

N: with equal & opposite forces

M: so they have equal and opposite momenta and, since they have the same mass, they have equal but opposite velocities. They travel just as fast, so they collide in the middle.

N: But what will happen if the masses are not the same?

M: I will take one of the weights out of this car. Now this car has half the mass of the other. By a show of hands, let me see your hypothesis about where they will collide now. How many think they will collide in the middle? How many on this side? How many on the other side? Let's try it and see. *(Demonstrate.)* They collided on this side, closer to the heavy car.

Truck/car slide

N: By Newton's 3rd law, the two cars still pulled on each other with equal and opposite forces so, by Newton's 2nd law, they gained equal and opposite momentum.

M: But the light car has smaller mass so, to have the same momentum, it needed to have a larger velocity.

N: The heavy car had more mass so, even though it had the same momentum, it had a smaller velocity.

M: The lighter car was faster, so it went farther before they crashed. That's why they collided over here by the heavy car.

Basketball/superball bounce

N: Here is another demonstration with the same idea. This big basketball has more mass than this little superball. When they collide, they will push on each other with equal and opposite forces—and gain equal and opposite momenta—but the little ball will bounce off much faster. *(Demonstrate.)*

Water rocket *Rocket slide*

M: This is how rockets work. The rocket pushes on the fuel to give it a force and the fuel pushes back on the rocket to give it a force.

N: The rocket and fuel start without any momentum. Afterward, the rocket has momentum one way and the fuel has momentum the other way. *(Demonstrate.)*

M: How come you got wet?

N: The water pushed the rocket that way but the rocket pushed the water this way—all over me!

Sail & fan

M: Here's a tricky example. Let's pretend this car is a sailboat. The boat has a fan on it that blows air this way. Which way will the boat go? Let me see your hypotheses. To the left? To the right? Stays still? *(Put it on the track.)*

N: The boat and the fan act like one object and the air is the other object. The boat pushes the air this way so, by Newton's 3rd law, the air pushes the boat the opposite way.

M: There is no momentum to begin with. The air gains momentum this way, so the boat gains momentum the opposite way. But now, it's going to get even trickier. *1st sailboat slide*. I'm going to leave the fan on but stick this sail on the boat. Now the air will shoot out of the fan and crash into the sail. Which way will the boat go now? Let me see your hypotheses. To the left? To the right? Stay still? *(Demonstrate.)*

N: It goes slowly in the direction the fan is blowing! Why is that?

Sailboat slide with explanation.

M: When the air crashes into the fan, some of it bounces back. Since the air gains momentum this way *(point)*, the boat must go this way.

N: The boat & sail pushed the air this way so the air pushed the boat & sail the other way.

Cannon *cannon slide*

N: Here is our last—and best—demonstration: the liquid nitrogen cannon. This is our cannon. This plastic bottle is our "cannon ball." Our "gunpowder" is this liquid nitrogen. Liquid nitrogen is very cold. You need to be careful with it; even though it is very cold it can burn you quite badly. It's so cold, it boils and evaporates when it is at room temperature; it thinks the room is boiling hot. I'll pour some in my cannon and it will start to evaporate. Now I'll pound in the cannon ball. Let me level the cannon and aim it. This valve is open right now so the pressure doesn't build up too much. Do you hear the escaping gas hissing? Now I'll close the valve and… *Cannon fires.* I'm going to do it again but you have to watch the cannon this time. *(Repeat demonstration with same patter. Fires.)*

M: *(Points to slide)* This is a great demonstration of conservation of momentum. How much momentum did the cannon have at first, before it was fired? (*Kids yell.)* It had no velocity so its momentum was zero. So, since momentum is conserved, the total momentum of the cannon and the cannon ball is still zero after the cannon is fired. The cannon ball has a small mass so it has a big velocity in this direction. The cannon has a large mass so it has a small velocity in the opposite direction. Their combined momentum remains zero throughout.

N: This is also a great demonstration of Newton's laws. The cannon pushes on the cannon ball to make it fly out. But the cannon ball pushes back with an equal and opposite force on the cannon—that's wy the cannon recoils in the opposite direction.

What is mass? slide

M: Now let's see how much you learned during our assembly. What is the correct definition of "mass?" (*Read choices.)* Raise your hand if you think the right answer is A? B? C? Oh, you are so smart, the correct answer is A. *Slide with answer.* Mass is the amount of stuff something has. B is velocity—how fast something is going. C is something that has lots of momentum: a heavy mass traveling with a large velocity.

Rifle question.

N: Here is a harder question. Before a rifle fires, the rifle and the bullet are both sitting still. What quantity is the same for the bullet and rifle after the gun fires. Is it "A", the mass? "B", the velocity? Or "C", the momentum? Raise your hands; how many think it is "A?" "B?" "C?"

Rifle answer.

N: The correct answer is “C.” The rifle and bullet have equal and opposite momentum. That’s conservation of momentum. The bullet has more velocity than the rifle but less mass.

Collision balls

M: Now it is time for you to do some experiments yourselves. Along the sides of the room we have some collision balls. With these you can see for yourself that momentum is conserved when the swinging balls hit the resting balls. You can launch one ball, two balls from one side, or balls from opposite directions. Please don’t swing the balls too hard or they tangle and break. Teachers, please supervise these stations.

N: If you want, you can line up to crash in these cars.

M: Another line will form here to do experiments with me on the air track. *Dismiss.*