Name: ______________________________ Date: _______________

Momentum Self-Assessment Key

Part A: Take a look at the key on the rest of the pages of this packet. Questions 1-3 include examples of using two different approaches for solving each problem, starting with a different momentum equation. No matter which approach you choose, the solution should be the same. For each problem in the key, circle the approach that is ***different*** from the one you used to solve the problem. Read through the approach you circled.

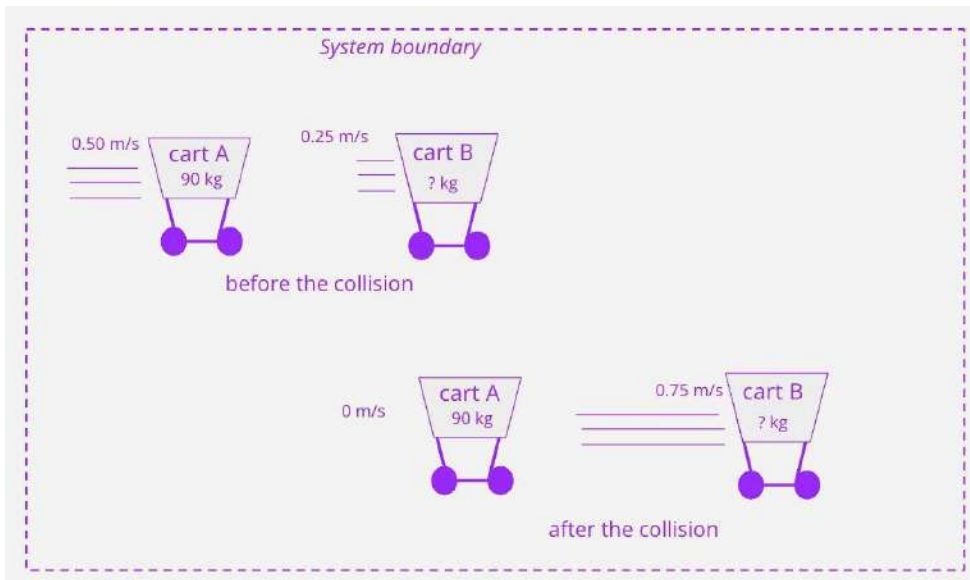
Part B: In thinking about applying mathematical models for conservation of momentum (equations) to solve problems, what steps of the process do you feel confident about? What would you like additional practice or help with?

Question 1: On windy days or on icy surfaces, unattended shopping carts in parking lots can end up rolling into other vehicles or other carts. A shopping cart corral is a structure that was designed to help prevent such collisions.

The data in the table to the right describe the outcome of a collision in which one cart filled with groceries (A) rolled into an empty cart (B).

Shopping cart	Mass	Velocity before the collision	Velocity after the collision
A	90 kg	+0.50 m/s	0.25 m/s
B	*30 kg*	0 m/s	0.75 m/s

1a) Draw and label the system. Include the parts interacting in the system, their related variables, and the boundary of the system.



1b) What does our mathematical model predict the mass of the empty cart B must be? Show how you solved for this unknown using one of our momentum equations.

Approach 1

$$m_A \times \Delta v_A + m_B \times \Delta v_B = 0$$

$$(90kg) \times (-0.25m/s) + m_B \times (0.75m/s) = 0$$

$$-2.25\ kg \cdot m/s + m_B \times (0.75m/s) = 0$$

$$+2.25\ kg \cdot m/s \qquad\qquad +2.25\ kg \cdot m/s$$

$$m_B \times (0.75m/s) = 2.25\ kg \cdot m/s$$

$$\div\ 0.75m/s \qquad \div\ 0.75m/s$$

$$\boxed{m_B = 30\ kg}$$

Approach 2

$$m_A \times v_{Af} + m_B \times v_{Bf} = m_A \times v_{Ai} + m_B \times v_{Bi}$$

$$(90kg) \times (+0.25m/s) + m_B \times (0.75m/s) = (90kg) \times (0.50m/s) + m \times (0m/s)$$

$$+2.25\ kg \cdot m/s + m_B(0.75m/s) = 4.50\ kg \cdot m/s$$

$$-2.25\ kg \cdot m/s \qquad\qquad -2.25\ kg \cdot m/s$$

$$m_B \times (0.75m/s) = 2.25\ kg \cdot m/s$$

$$\div\ 0.75m/s \qquad \div\ 0.75m/s$$

$$\boxed{m_B = 30\ kg}$$

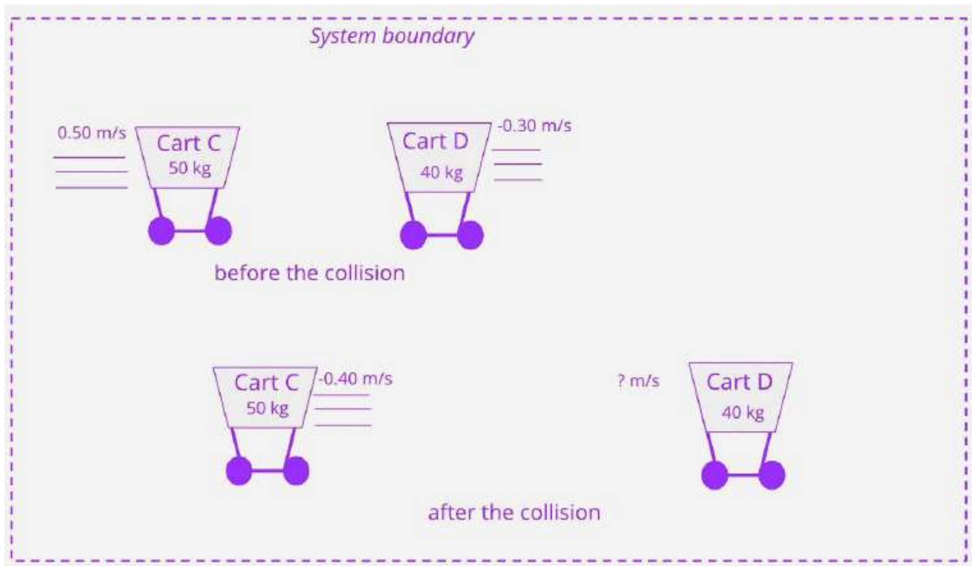
1c) Why does your use of this equation provide a reasonable approximation of the outcomes for the system you defined?

- *The 2-cart system means that the collision forces are within the system and there are minimal external forces on the system.*

Question 2: On windy days or on icy surfaces, unattended shopping carts in parking lots can end up rolling into other vehicles or other carts. A shopping cart corral is a structure that was designed to help prevent such collisions.

These data describe the outcome of a collision between 2 grocery carts, one with some groceries in it (C) and one with less in it (D).

Shopping cart	Mass	Velocity before the collision	Velocity after the collision
C	50 kg	+0.50 m/s	-0.30 m/s
D	40 kg	-0.40 m/s	+ 0.60 m/s



2a) Draw and label the system. Include the parts interacting in the system, their related variables, and the boundary of the system.

2b) What does our mathematical model predict the final velocity of cart D would be? Show how you solved for this unknown using one of our momentum equations.

Approach 1

$$m_C * \Delta v_C + m_D * \Delta v_D = 0$$

$$(50\ kg) * (-0.8\ m/s) + (40\ kg) * \Delta v_D = 0$$

$$-40\ kg \cdot m/s + (40\ kg) * \Delta v_D = 0$$

$$+40\ kg \cdot m/s \qquad\qquad +40\ kg \cdot m/s$$

$$(40\ kg) * \Delta v_D = 40\ kg \cdot m/s$$

$$\div (40\ kg) \qquad \div (40\ kg)$$

$$\Delta v_D = +1\ m/s$$

Since the initial velocity was -0.40 m/s and the velocity changed by +1 m/s, this would result in a final velocity of +0.6 m/s.

Approach 2

$$m_C * v_{Cf} + m_D * v_{Df} = m_C * v_{Ci} + m_D * v_{Di}$$

$$(50kg) * (-0.3m/s) + (40kg) * v_{Df} = (50kg) * (0.5m/s) + (40kg) * (-0.4m/s)$$

$$-15\ kg \cdot m/s + (40\ kg) * v_{Df} = 25\ kg \cdot m/s - 16\ kg \cdot m/s$$

$$-15\ kg \cdot m/s + (40\ kg) * v_{Df} = 9\ kg \cdot m/s$$

$$+15\ kg \cdot m/s \qquad\qquad +15\ kg \cdot m/s$$

$$(40\ kg) * v_{Df} = 24\ kg \cdot m/s$$

$$\div (40\ kg) \qquad \div (40\ kg)$$

$$v_{Df} = +0.6\ m/s$$

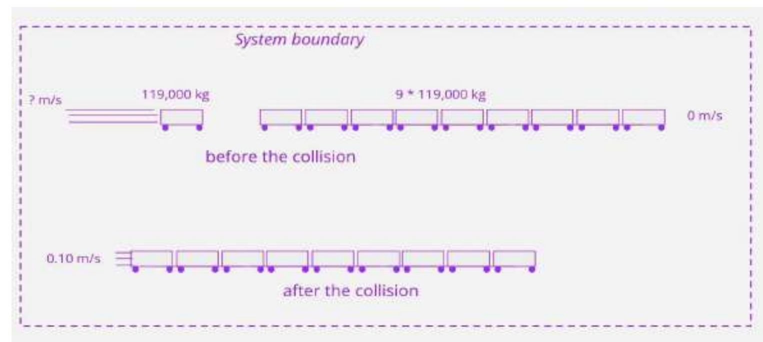
2c) Why does your use of this equation provide a reasonable approximation of the outcomes for the system you defined?

- *The 2-cart system means that the collision forces are within the system and there are minimal external forces on the system.*

Question 3: Switcher engines are used to move train cars from one track to another in train yards, to prepare a long chain of train cars for transport out of the yard by a larger engine. To save time and fuel in shuffling cars around, railyard workers sometimes uncouple a car the engine has been pushing, so it coasts along the track until it collides with the chain of stationary cars that it needs to be connected to.

- The single tanker car is rolling at a nearly constant speed when it collides with and couples to 9 other tanker cars.
- All of these cars end up moving together at 0.1 m/s as a result of this collision, in the same direction that the single tanker car was initially moving.
- Every tanker car has a mass of 119,000 kg.

3a) Draw and label the system. Include the parts interacting in the system, their related variables, and the boundary of the system.



3b) How fast must the tanker car have been moving before such a collision?

Approach 2

$$m_C \times v_{Cf} + m_D \times v_{Df} = m_C \times v_{Ci} + m_D \times v_{Di}$$

$$(9 * 119{,}000\text{kg}) \times (1\text{ m/s}) + (119{,}000\text{kg}) \times (1\text{ m/s}) = (9 * 119{,}000\text{kg}) \times (0.0\text{m/s}) + (119{,}000\text{kg}) \times v_{Di}$$

$$1{,}071{,}000\text{ kg}\cdot\text{m/s} + 119{,}000\text{ kg}\cdot\text{m/s} = 0 + (119{,}000\text{kg}) \times v_{Di}$$

$$1{,}190{,}000\text{ kg}\cdot\text{m/s} = (119{,}000\text{kg}) \times v_{Di}$$

$$\div\ 119{,}000\text{ kg} \qquad \div\ 119{,}000\text{ kg}$$

$$10\text{ m/s} = \Delta v_{Di}$$

$$v_{Di} = +10\text{ m/s}$$

Approach 1

$$m_C \times \Delta v_C + m_D \times \Delta v_D = 0$$

$$(9 * 119{,}000\text{ kg}) \times (1\text{ m/s}) + (119{,}000\text{ kg}) \times \Delta v_D = 0$$

$$1{,}071{,}000\text{ kg}\cdot\text{m/s} + (119{,}000\text{ kg}) \times \Delta v_D = 0$$

$$-\ 1{,}071{,}000\text{ kg}\cdot\text{m/s} \qquad -\ 1{,}071{,}000\text{ kg}\cdot\text{m/s}$$

$$(119{,}000\text{ kg}) \times \Delta v_D = 1{,}071{,}000\text{ kg}\cdot\text{m/s}$$

$$\div\ 119{,}000\text{ kg} \qquad \div\ 119{,}000\text{ kg}$$

$$\Delta v_D = -9\text{ m/s}$$

If the final velocity was 1 m/s and the velocity changed by -19m/s,, then

$$\Delta v_D = v_{Df} - v_{Di}$$

$$-9 = 1 - v_{Di}$$

$$-1 \qquad -1$$

$$-10 = -v_{Di}$$

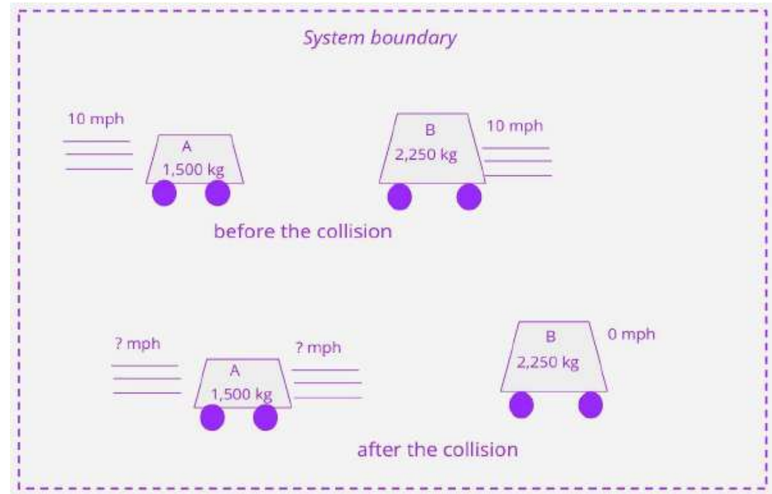
So $v_{Di} = 10$ m/s

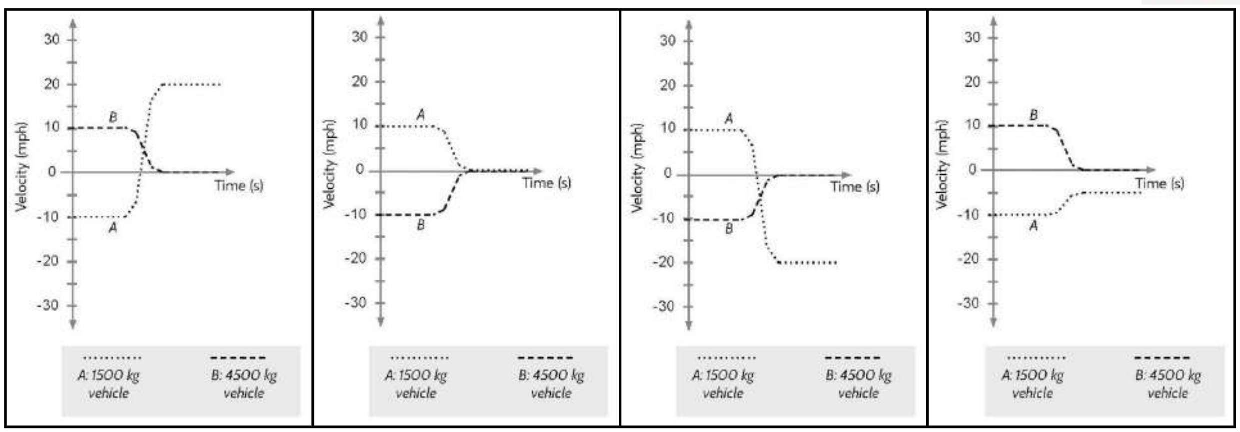
3c) Is this collision elastic or inelastic? How do you know?

This is an inelastic collision because the final velocity of the newly added car is the same as the final velocity of the chain of cars, as all of them move forward and together. None of them bounce off each other in the collision.

Question 4: A head-on collision occurs between 2 vehicles. The smaller vehicle is 1,500 kg and is moving at 10 mph before the collision. The larger car is 2,250 kg and is moving at 10 mph in the opposite direction before the collision. The larger vehicle comes to a stop as a result of the contact forces in the collision. **For each graph, indicate whether it shows the expected velocity change in the smaller vehicle (write yes or no for each, and explain why).**

4a) Draw and label the system. Include the parts interacting in the system, their related variables, and the boundary of the system.





4b) Yes. The graph shows that the smaller vehicle was moving at -10 mph and opposite in direction to the larger vehicle. Once it collided with the larger vehicle, it started to move in the opposite direction at 20 mph, which was its final velocity, and had a velocity change of +30 mph, which is 3 times that of the larger vehicle and is also opposite in value. That makes sense because the larger vehicle is 3 times more massive.	4c) No. Though the graph shows the correct magnitude for the final velocity of the larger vehicle, it does not show the expected velocity change in the smaller vehicle. It shows that both vehicles came to a full stop after the collision, which is a same-magnitude velocity change. But the smaller-mass vehicle needs to have a velocity change that is 3 times that of the larger vehicle.	4d) Yes. The graph shows that the smaller vehicle was moving at 10 mph and opposite in direction to the larger vehicle. Once it collided with the larger vehicle, it started to move in the opposite direction at +20 mph, which was its final velocity and is also opposite in value. That makes sense because the larger vehicle is 3 times more massive.	4e) No. Though this graph shows the correct magnitude for the final velocity of the larger vehicle, it does not show the expected velocity change in the smaller vehicle. It shows that the smaller cart only slowed down from 10 mph to 5 mph, which is a smaller-magnitude velocity change than that of the larger vehicle. But it should be a larger-magnitude velocity change than that of the larger vehicle.