Physics Workshop
Momentum and its Conservation
Suggested Checkpoint Questions with Answers

- Checkpoint following 2(b):

1. Why are conserved quantities useful for solving physics problems?
2. Can there be a net vertical force on the snowball if it is thrown horizontally? If not, what force is balancing its weight?
3. Can there be a net vertical force on Maria? What would happen if there were one?

- Checkpoint following 2(d):

1. How do you decide if momentum is conserved in a particular situation?
2. When are two forces on different objects equal in magnitude?
3. Newton's 2^{nd} Law is $F_{net} = ma$. Can you rewrite this law in terms of momentum to give a mathematical basis to your answer to the previous question?

- Checkpoint following 3(d):

1. What's your chosen coordinate system?
2. If you had chosen a different coordinate system, would you get different answers?
3. How do you determine the *direction* of Maria's motion after she throws the snowball?

- Checkpoint following 4(c):

1. Could you have decided whether or not momentum is conserved for the ball/wall system just by thinking about it (without making free-body diagrams)? Explain how.
2. In the case of the ball and the wall, is there any system that includes the ball and wall (and possibly other things) for which momentum *is* conserved?

Answers to checkpoint questions:

- Checkpoint following 2(b):

1. Whenever you encounter a conserved quantity, you're lucky because you can then write down an equation that represents this conservation principle. This equation will represent a relationship between "before" and "after" some physical event occurs.
2. If there were a net vertical force on the snowball, it would be accelerating vertically, which is not the case. So Maria's hand must in fact be exerting a vertical force on the snowball to balance its weight, in addition to the horizontal one that accelerates it forward.
3. Maria is not accelerating vertically, so there is no net vertical force on her either. If there were one, she would be accelerating either up into the air or down into the ground.

- Checkpoint following 2(d):

1. When the *net force is zero* on an object or system of objects, then momentum is conserved for that system.
2. Newton's 3rd Law tells us that F_{AB} (the force A exerts on B) is equal in magnitude to F_{BA} (the force B exerts on A). However, the forces are in opposite directions.
3. Newton's Law can be rewritten as follows: This shows that when the net force is zero, the change in momentum is zero, and thus momentum is conserved.

$$F_{\text{net}} = ma = m\frac{\Delta v}{\Delta t} = \frac{\Delta(mv)}{\Delta t} = \frac{\Delta p}{\Delta t}$$

- Checkpoint following 3(d):

2. The answers represent actual physical outcomes and so had better not depend on your choice of coordinate systems. The key is to choose a coordinate system, write it down, and stick to it for the duration of your solution.
3. If Maria's final velocity comes out positive, then she'll be moving in the positive direction according to your chosen coordinate system. If her velocity comes out negative, she'll be moving in the direction that you called negative.

- Checkpoint following 4(c):

1. Just by thinking it should be clear that: a) the momentum of the wall remains constant, since it never moves; and b) the momentum of the ball doesn't remain constant, since it reverses direction. Therefore the total momentum, which is the sum of the ball's momentum plus the wall's momentum, is not conserved.
2. Imagine extending the "system" you're thinking about to include the planet Earth. Then the net force on the ball + wall + Earth system is zero, at least when it comes to the forces they exert on each other. (Of course, the Earth feels gravitational forces from the Sun and all other astronomical objects.)