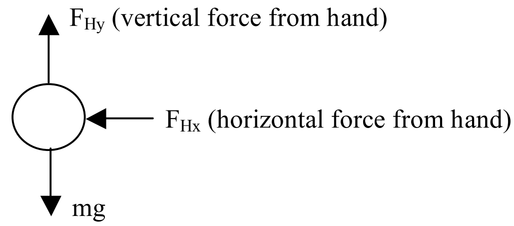
Physics Workshop **Momentum and its Conservation** **Solutions**

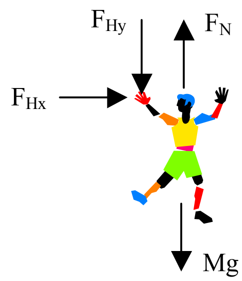
1. A quantity is *conserved* if its total value stays the same. The quantity can change forms or be shared differently between objects, but its total value remains constant. *Momentum* is the product of mass and velocity for any object $(\vec{p} = m\vec{v})$. It is therefore a vector. *Conservation of momentum* means that when you add the momentum of various objects in a vector sum, that sum stays the same. This week's problems are mostly about when momentum is and isn't conserved.

2. (a)



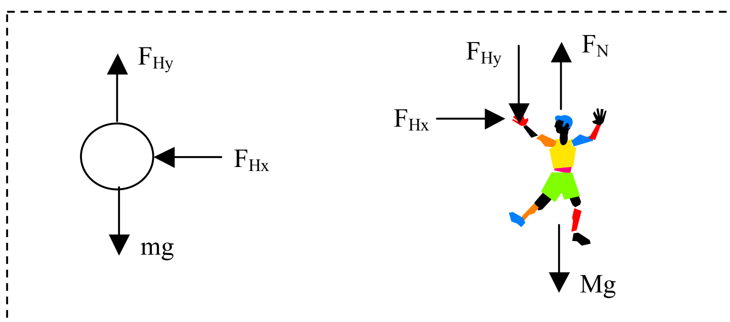
Yes, there is a net force on the snowball as it's being thrown. It's the horizontal force from Maria's hand, which accelerates the snowball forward as she throws it.

(b)



Yes, there is a net force on Maria as she throws. It's the horizontal force from the snowball.

(c)

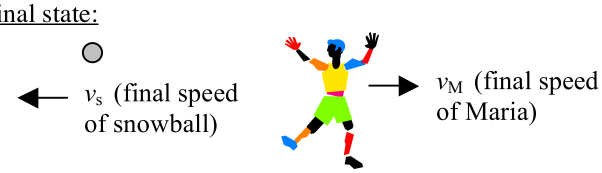


On the two objects (snowball and Maria) combined, the net force is zero.

(d) There's a net force on the snowball, so its momentum *isn't* conserved. There's a net force on Maria, so her momentum *isn't* conserved. However, the net force on the combination of the snowball plus Maria is zero, so their combined momentum *is* conserved!

3. (a) Initial state:

Final state:



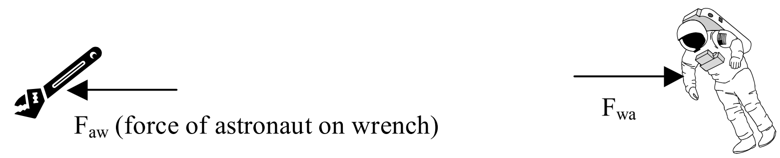
(b) $p_{ix} = p_{fx}$:

$0 = m_M v_M - m_s v_s$

(c) $v_M = m_s v_s / m_M$

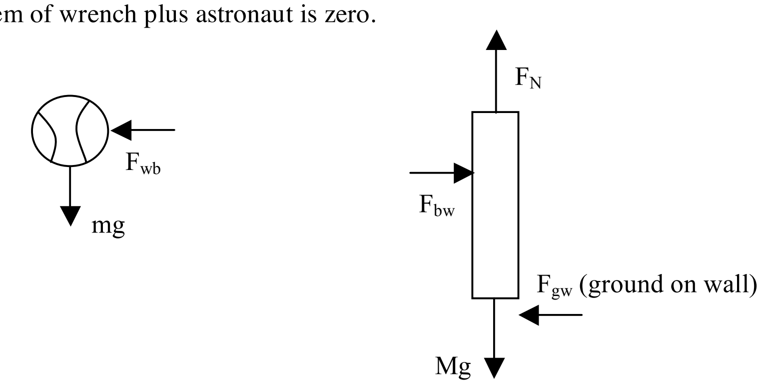
(d) Using the numbers given, $v_M = 0.2$ m/s. (To the right, since the velocity is positive.)

4. (a)



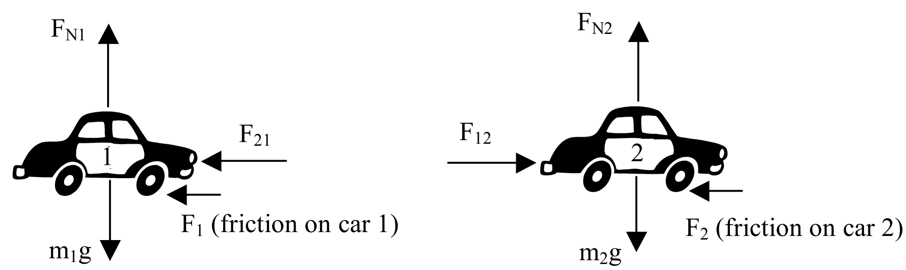
(i) Is momentum conserved for the wrench? No. There's a net force on the wrench.
(ii) Is momentum conserved for the astronaut? No. There's a net force on the astronaut.
(iii) Is momentum conserved for the wrench/astronaut system? Yes! The net force on the combined system of wrench plus astronaut is zero.

(b)



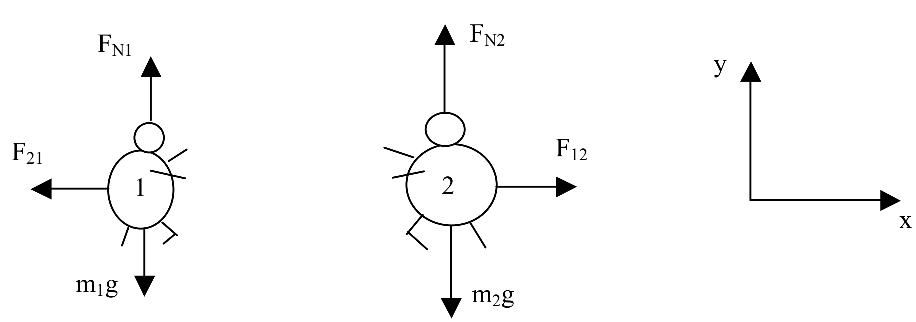
(i) Is momentum conserved for the ball? No, there's a net force on it (in both directions).
(ii) Is momentum conserved for the wall? Yes! There's no net force on the wall. This is clear because the wall doesn't move, so its initial momentum and final momentum are both zero. There must be a force on the wall from the ground to balance the force of the ball hitting it.
(iii) Is momentum conserved for the system consisting of the ball and the wall? No. Now the two objects combined clearly have a net force acting on them, so momentum is not conserved for the system. This is also clear because the ball's momentum reverses direction, but the wall's momentum remains the same (zero).

(c)



(i) Is momentum conserved for each car individually? No, there's a net force on each car.
(ii) Is momentum conserved for the system consisting of both cars? It's not *exactly* conserved, because there is a small net force on the system due to friction. However, if this force is relatively small and the time of the collision is very short, we could say that momentum is *approximately* conserved.

5. (a)



(b) Yes, their combined momentum is conserved, because the net force on the two wrestlers combined is zero.

(c) See above for one possible coordinate system. In this system, the initial velocity of wrestler 1 is positive and that of wrestler 2 is negative. So conservation of momentum looks like this:

$$m_1 v_1 + m_2 v_2 = (m_1 + m_2) v_f$$

$$\Rightarrow v_f = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

$$= \frac{(100kg)(2m/s) + (150kg)(-1m/s)}{250kg}$$

$$= 0.2m/s$$

The fact that the answer came out positive means that the final velocity is to the right.

6. This is another case where momentum is conserved, since Shaq and his trophy exert equal and opposite forces on each other:

$$m_1 v_1 + m_2 v_2 = m_1 v_{1f} + m_2 v_{2f}$$

$$0 = (300lbs)(v_{1f}) + (50lbs)(6m/s)$$

$$\Rightarrow v_{1f} = -1m/s$$

The negative sign in this case indicates that Shaq will end up moving in the direction opposite the way he threw his trophy, since the trophy was assigned a positive velocity in the equation. At the constant rate of 1 m/s, it will take Shaq 30 s to travel 30 m and reach the edge of the court.

<u>Additional Questions:</u>

1. The satellite exerts a backward force on the ions, which in turn exert a forward force on the satellite. The momentum of the ions plus the satellite is conserved.

2. The time of the collision between the cars (during which they are exerting forces on each other) is usually very short. Therefore, the change in momentum of the system is close to zero even if there is a net force on the cars (from friction between their tires and the road, for example) since $\Delta p = F_{net}\Delta t$. So even if momentum isn't exactly conserved, it's close to being conserved.

3. Consider a collision between a school bus and a car. In the collision, the change in momentum of the bus plus the change in momentum of the car must add to zero if momentum is conserved. However, because the bus has a very large mass compared to the car, this change in momentum leads only to a small change in velocity. Therefore the bus accelerates only slightly, and the passengers are not likely to be injured. Of course, if the bus hits a building or something else with a lot of inertia, this argument is not longer valid.