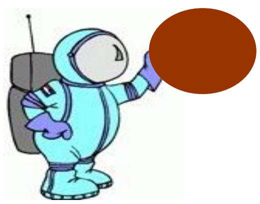
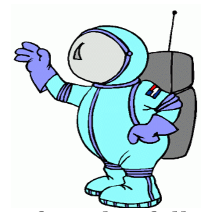
MOMENTUM AND IMPULSE KEY

***Instructions**: Use complete sentences and your knowledge of momentum and impulse to answer the following questions completely in your journal. Show work when necessary.*

1. Consider Kirk and Spock who are playing catch with a little moon they found deep in space. Kirk, Spock, and the moon all have a mass of 50. kg. Initially, all objects have a velocity of zero; therefore, $p_{total} = 0$ N·s.



At the start:
$m = 50.$ kg
$v = 0\ ^{m}/_{s}$
$p_{total} = 0$ N·s



In your journal, diagram all 3 objects and label each with its momentum after the following has occurred:

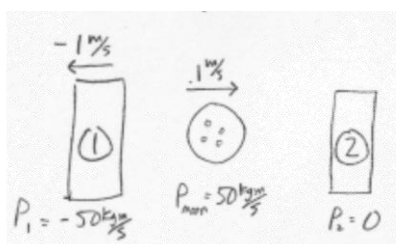
a. Kirk (on the left) throws the moon to Spock (on the right) with a velocity of 1.0 $^{m}/_{s}$.

$$p_{moon} = m_{moon} v_{moon} = (50\ \text{kg}) \cdot (1.0\ ^{\text{m}}/_{\text{s}})$$

$$\boxed{\boldsymbol{p_{moon} = 50\ ^{\text{kg}\cdot\text{m}}/_{\text{s}}}}$$

$$p_{total} = 0 = p_{moon} + p_{Kirk}$$

$$\boxed{\boldsymbol{p_{Kirk} = -50\ ^{\text{kg}\cdot\text{m}}/_{\text{s}}}}$$

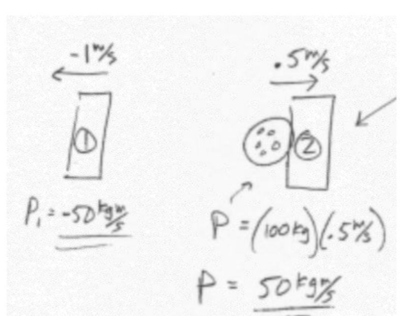


b. Spock catches it.

$$p_{before} = p_{after} \rightsquigarrow 50\ ^{\text{kg}\cdot\text{m}}/_{\text{s}} = (m_{moon} + m_{Spock}) v_{after}$$

$$50\ ^{\text{kg}\cdot\text{m}}/_{\text{s}} = (50\ \text{kg} + 50\ \text{kg}) \cdot v_{after}$$

$$\boxed{\boldsymbol{v_{after} = 0.5\ ^{\text{m}}/_{\text{s}}}}$$



c. Spock throws it back with a velocity of -2.0 $^{m}/_{s}$.

$$p_{before} = p_{after} \rightsquigarrow 50\ ^{kg \cdot m}/_{s} = p_{moon} + p_{Spock}$$

$$p_{moon} = m_{moon} v_{moon} = (50\ \text{kg}) \cdot (-2.0\ ^{m}/_{s})$$

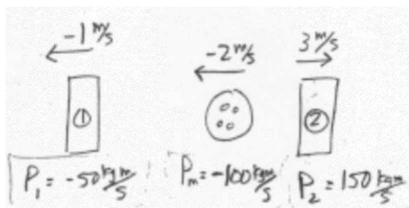
$$\boxed{\boldsymbol{p_{moon} = -100\ ^{kg \cdot m}/_{s}}}$$

$$p_{before} = p_{moon} + p_{Spock} \rightsquigarrow 50\ ^{kg \cdot m}/_{s} = -100\ ^{kg \cdot m}/_{s} + p_{Spock}$$

$$\boxed{\boldsymbol{p_{Spock} = 150\ ^{kg \cdot m}/_{s}}}$$

$$p_{Spock} = m_{Spock} v_{Spock} \rightsquigarrow 150\ ^{kg \cdot m}/_{s} = (50\ \text{kg}) \cdot v_{Spock}$$

$$\boxed{\boldsymbol{v_{Spock} = 3.0\ ^{m}/_{s}}}$$



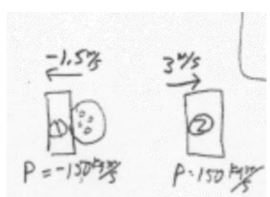
d. Kirk catches it.

$$p_{before} = p_{after} \rightsquigarrow p_{moon} + p_{Kirk} = (m_{moon} + m_{Spock}) v_{after}$$

$$-100\ ^{kg \cdot m}/_{s} + \left(-50\ ^{kg \cdot m}/_{s}\right) = (50\ \text{kg} + 50\ \text{kg})\ v_{after}$$

$$-150\ ^{kg \cdot m}/_{s} = (100\ \text{kg}) \cdot v_{after}$$

$$\boxed{\boldsymbol{v_{after} = -1.5\ ^{m}/_{s}}}$$



2. Pat pushes his older sister with a force of $2\bar{0}0$ N for 0.50 seconds on a frozen pond.
   a. What was his sister's change in momentum from this impulse?

$$I = \Delta p = F \cdot \Delta t = (200\ \text{N})(0.50\ \text{s})$$
$$\boxed{\Delta \boldsymbol{p} = \mathbf{1\bar{0}0\ N \cdot s}}$$

   b. What was Pat's corresponding change in momentum?

$$\boxed{\Delta \boldsymbol{p} = \mathbf{1\bar{0}0\ N \cdot s}}$$

   c. If Pat weighs 600. N, what would be his resulting velocity? Assuming he started from rest:

$$F_g = mg \rightsquigarrow m = \frac{F_g}{g} = \frac{600\ \text{N}}{9.80\ \text{m}/_{\text{s}^2}} = 61.2\ \text{kg}$$
$$\Delta p = m \cdot \Delta v \rightsquigarrow v_2 - v_1 = \frac{\Delta p}{m}$$
$$v_2 - 0 = \frac{1\bar{0}0\ \text{N} \cdot \text{s}}{61.2\ \text{kg}}$$
$$\boxed{\boldsymbol{v_2} = \mathbf{1.63\ ^{m}/_{s}}}$$

3. A 0.500 kg hockey puck, initially moving at 2.00 $^{\text{m}}/_{\text{s}}$, is smacked by a highly skilled player's stick with a force of 600. N in the direction of motion. The final velocity of the puck is 32.0 $^{\text{m}}/_{\text{s}}$!
   a. What is the impulse exerted on the puck?

$$I = \Delta p = m \cdot \Delta v = m(v_2 - v_1) = (0.5\ \text{kg})(32\ ^{\text{m}}/_{\text{s}} - 2\ ^{\text{m}}/_{\text{s}})$$
$$\boxed{\boldsymbol{I} = \mathbf{15.0\ N \cdot s}}$$

   b. How much time was the stick in contact with the puck?

$$I = F \cdot \Delta t \rightsquigarrow \Delta t = \frac{I}{F} = \frac{15\ \text{N} \cdot \text{s}}{600.\ \text{N}}$$
$$\boxed{\Delta \boldsymbol{t} = \mathbf{0.0250\ s}}$$

   c. What force would be required to bring the puck to a stop in 0.100 sec?

$$I = \Delta p = m \cdot \Delta v = m(v_2 - v_1) = (0.5\ \text{kg})(0\ ^{\text{m}}/_{\text{s}} - 32\ ^{\text{m}}/_{\text{s}}) = -16\ \text{N} \cdot \text{s}$$
$$I = F \cdot \Delta t \rightsquigarrow F = \frac{I}{\Delta t} = \frac{-16\ \text{N} \cdot \text{s}}{0.10\ \text{s}}$$
$$\boxed{\boldsymbol{F} = \mathbf{16\bar{0}\ N}}$$

4. We claim that momentum is conserved. Yet most moving objects eventually slow down and stop. Explain.

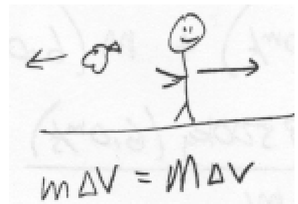
   When friction acts on an object, momentum is being transferred to the other object (usually the Earth).

5. When a person jumps from a tree to the ground, what happens to the momentum of the person upon striking the ground?

It is transferred to the Earth! The resulting change in velocity for the Earth is <u>SO</u> very small, that we say the Earth "absorbed" the momentum.

6. It is said that in ancient times a rick man with a bag of gold coins froze to death stranded on the surface of a frozen lake. Because the ice was frictionless, he could not push himself to shore. What could he have done to save himself had he not been so miserly?

He could have thrown the bag of coins!



7. It used to be common wisdom to build cars o be as rigid as possible to withstand collisions. Today, tough, cars are designed to have "crumple zones" that collapse upon impact. What advantage does this have?

The crumple zone increases the amount of time over which the impact force is acting on the car, thus lessening the impact force!

$$\boldsymbol{I = F \cdot \Delta t} \textbf{ and } \boldsymbol{I = \Delta p = m \cdot \Delta v} \textbf{ so } \boldsymbol{F \cdot \Delta t = m \cdot \Delta v} \textbf{ !}$$