Action-Reaction and Momentum Conservation

Read from **Lesson 2 of** the **Momentum and Collisions** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/momentum/u4l2a.html
http://www.physicsclassroom.com/Class/momentum/u4l2b.html

MOP Connection: Momentum and Collisions: sublevels 4, 5 and 6

Newton's Third Law and Collisions: In a collision between object 1 and object 2, both objects encounter a force resulting from their mutual interaction with each other. The force on object 1 (F_1) is equal to and opposite in direction as the force on object 2 (F_2).

Plus a Little Logic: The forces which these two objects experience endure for the same amount of time. Since $\mathbf{F_1 = - F_2}$ and $\mathbf{t_1 = t_2}$ it stands to reason that $\mathbf{F_1 \cdot t_1 = - F_2 \cdot t_2}$. This is to say that each object encounters the same impulse. If this is the case, then one can also reason that each object must experience the same momentum change.

Use the above principles to answer the next four questions.

1. The club head (m=0.170 kg) of a golf club collides with a golf ball (m=0.046 kg) at rest upon a tee.

a. Which object experiences the greatest force?	club head	golf ball	both the same
b. Which object experiences the greatest impulse?	club head	golf ball	both the same
c. Which object experiences the greatest Δmomentum?	club head	golf ball	both the same
d. Which object experiences the greatest acceleration?	club head	golf ball	both the same

2. A woman (m = 45 kg) is kneeling on the shoulders of a man (m = 70 kg) in pair figure skating. The man gracefully tosses the woman forward through the air.

a. Which object experiences the greatest force?	man	woman	both the same
b. Which object experiences the greatest impulse?	man	woman	both the same
c. Which object experiences the greatest Δmomentum?	man	woman	both the same
d. Which object experiences the greatest acceleration?	man	woman	both the same

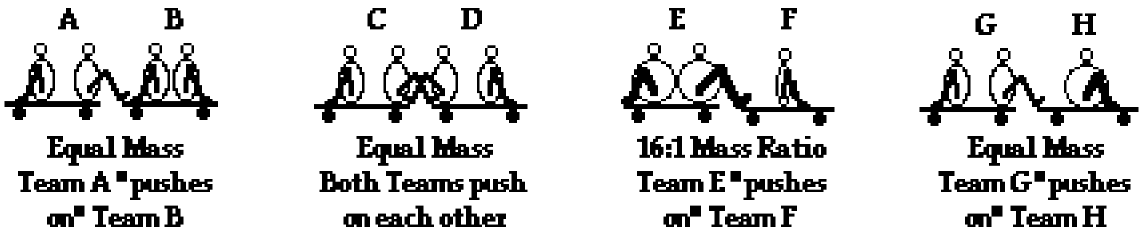
3. A moving cue ball collides head-on with the eight ball that is at rest upon the pool table. Assume the balls have the same mass.

a. Which object experiences the greatest force?	cue ball	8-ball	both the same
b. Which object experiences the greatest impulse?	cue ball	8-ball	both the same
c. Which object experiences the greatest Δmomentum?	cue ball	8-ball	both the same
d. Which object experiences the greatest acceleration?	cue ball	8-ball	both the same

4. A large truck and a Volkswagon (VW) beetle have a head-on collision.

a. Which object experiences the greatest force?	truck	VW	both the same
b. Which object experiences the greatest impulse?	truck	VW	both the same
c. Which object experiences the greatest Δmomentum?	truck	VW	both the same
d. Which object experiences the greatest acceleration?	truck	VW	both the same

In a series of physics demos, students of varying mass are placed on large *massless* carts and deliver impulses to each other's carts, thus changing their momenta. In some cases, the carts are loaded with equal mass; in other cases they are unequal. In some cases, the students push off each other; in other cases, only one team does the pushing. These situations are depicted below.



5. In which cases (AB, CD, EF, GH) do the carts encounter unequal impulses? ___________ Explain.

6. In which cases do the carts encounter unequal momentum changes? ___________ Explain.

7. In which cases do the carts encounter unequal velocity changes? ___________ Explain.

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8. Identify the following statement as True or False. If false, correct the statement.

   According to the law of momentum conservation, if a collision occurs in an isolated system, then any object involved in the collision will conserve its own momentum.

9. Identify the following statement as True or False. If false, correct the statement.

   A person pushes down on the Earth in order to jump into the air. The person gains upward momentum but the Earth *doesn't even budge*. In this example, the law of momentum conservation does not hold.

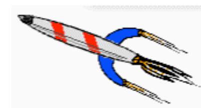
10. Miles Tugo and Ben Travlun are riding in a bus at highway speed on a nice summer day when an unlucky bug splatters onto the windshield.

    Miles and Ben begin discussing the physics of the situation. Miles suggests that the momentum change of the bug is much greater than that of the bus. After all, argues Miles, there was no noticeable change in the speed of the bus compared to the obvious change in the speed of the bug. Ben disagrees entirely, arguing that both bug and bus encounter the same force, momentum change, and impulse.

    Who do you agree with? _______ Support your answer.

11. The gunpowder explosion in a gun results in an expansion of gases that cause a bullet to be propelled forward. The gun in turn "kicks" or "recoils" backwards. The recoil momentum of a gun that kicks is _______ the momentum of the bullet that it fires.
a. more than b. less than c. the same as

12. Airplane wings are designed to push air downwards during take off. Explain it is necessary for the wing to push air downwards.



13. There is no *physical object* in space upon which a rocket is able to push off of. Nonetheless a rocket is able to accelerate in space. How can this be? Explain.

14. Kent Swimm (who is taking physics for the second year in a row, and not because he likes it) has rowed his boat to within three feet of the dock. In an effort to save a little time, he decides that he will simply jump off his boat onto the dock, turn around and then tie down his boat. Explain to Kent why this would not be too wise an idea.

15. Consider the interaction between a large cannon and the cannonball that it fires. During the explosion, which object experiences the greatest ...

a. force (F)?	Cannon	Cannonball	Both the same
b. time duration (t) of the force?	Cannon	Cannonball	Both the same
c. impulse (F•t)?	Cannon	Cannonball	Both the same
d. momentum change (m•Δv)?	Cannon	Cannonball	Both the same
e. velocity change (Δv)?	Cannon	Cannonball	Both the same
f. acceleration (a)?	Cannon	Cannonball	Both the same

16. Express your understanding of momentum conservation by filling in the following <u>momentum tables</u>:

a. Kent Swimm is drifting towards the dock and suddenly jumps forward to *dock* his boat.

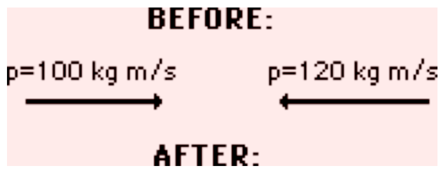
	Before Explosion	After Explosion
Kent	50	200
Boat	100	
Total		

b. A cannon is loaded with a ball, placed on a cart, set in motion and fired.

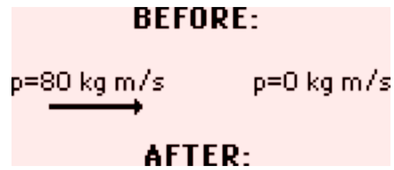
	Before Explosion	After Explosion
Cannon	121	117
Ball	5	
Total		

17. The following two systems are isolated systems. The vector nature of momentum is depicted by the diagram that shows momentum vectors for the two colliding objects before the collision. Express your understanding of momentum conservation by drawing and labeling the magnitude of the after-collision momentum vector.

a. A fullback collides in mid-air with a linebacker above the goal line. The linebacker and fullback hold each other and move together after the collision.



b. A medicine ball is thrown to a clown who is at rest upon the ice. After the "collision" (i.e., the catch), the clown and ball travel together across the ice.



18. If a ball is projected upward from the ground with ten units of momentum, what is the momentum of recoil of the Earth? ____________ Do we feel this? Explain.

19. If a 5-kg bowling ball is projected upward with a velocity of 2.0 m/s, then what is the recoil velocity of the Earth (mass = 6.0×10^{24} kg). **PSYW**

20. A 120 kg lineman moving west at 2 m/s tackles an 80 kg football fullback moving east at 8 m/s. After the collision, both players move east at 2 m/s. Draw a vector diagram (similar to the one drawn in question #17) in which the before- and after-collision momentum of each player is represented by a momentum vector. Label the magnitude of each momentum vector.

Before Collision: **After Collision:**

Write a few sentences to explain how this collision shows that momentum is conserved. Use some numbers in your explanation.