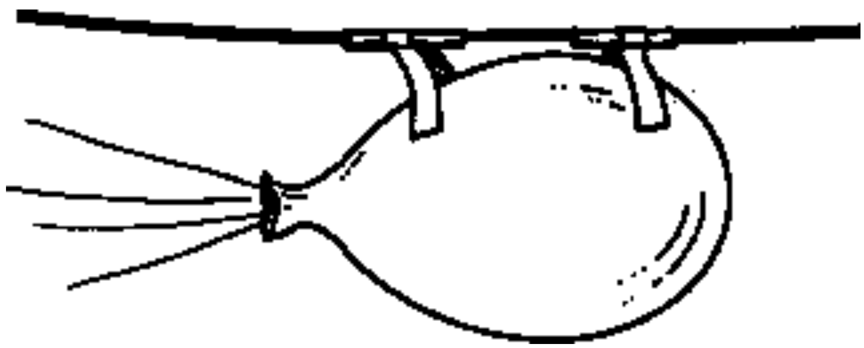
NEWTON'S THIRD LAW OF MOTION

PROBLEM PRESENTATION / EXPLORATION

A. Balloon Race

1. Let's have a balloon race.
2. Divide the class into groups and give each group a balloon, a plastic straw, some tape and a 10 meter length of fishing line.
3. The purpose is to figure out how to shoot the balloon from the back of the room to hit the blackboard at the front of the room, using the fishing line as a track for the balloon to follow.
4. The race will be timed and a winner determined.
5. The fishing line will be attached to the top of the blackboard. The other end may be held in a team member's hand so that the line is taut throughout the time of the flight. The line may not be moved up and down to help the balloon move toward the blackboard, however.
6. After blowing up the balloon and pinching off the mouth, the straw should be taped to the balloon.
7. Still holding the balloon closed, the fishing line should be threaded through the straw.



8. Upon releasing the balloon it should take off up the fishing line toward the target.

B. Straw Rockets

1. If you don't want to use fishing line to restrict the path of the balloon rocket, a straw rocket can be constructed that needs no string or balloon. Instead, a bottle launcher is required and can be made from a flexible plastic bottle.
2. A piece of glass tubing should be inserted into a rubber stopper.

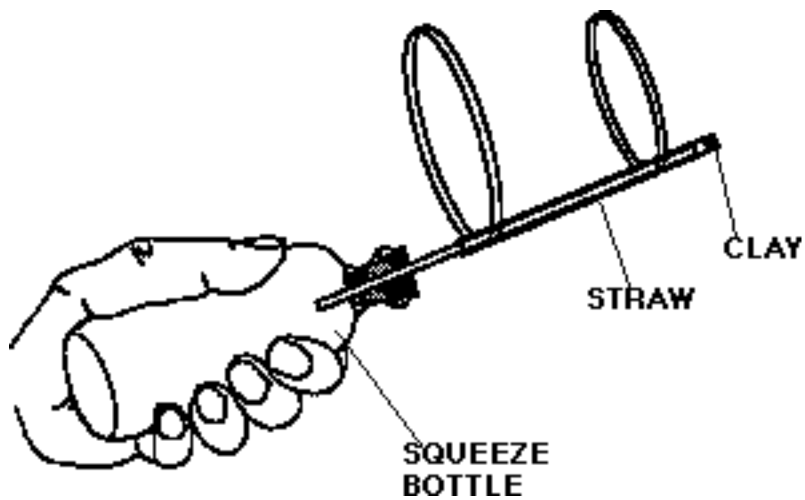
> CAUTION: Either you should insert the glass tubing ahead of time, or you must provide careful instruction on this process. Inserting glass into rubber stoppers and the resulting accidents that occur from the glass snapping are very common and dangerous.

The rubber stopper should fit the bottle tightly. The length of the glass tubing should be about 30 cm and its diameter must be smaller than the straw that will be used in the rocket.

3. The straw rocket is made by tightly closing one end of the straw with a wad of modeling clay. Tape two paper loops to the straw. The smaller

one should be toward the end with the clay and the larger one attached close to the other end. These give stability to the projectile.

4. Slip the straw rocket over the glass tubing of the launcher.
5. Aim the rocket at the blackboard and squeeze the bottle with a sudden motion.



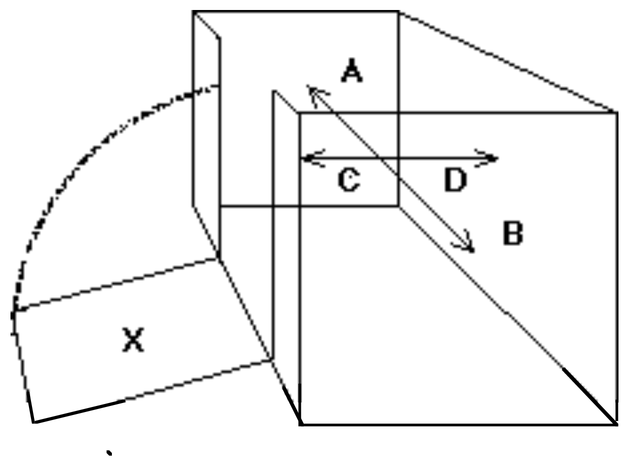
CLASS RESPONSE / CONCEPT INVENTION

A. Common Misconception

1. Nine out ten people would probably explain the balloon rocket's motion in the following way: "The air issues from the back of the balloon, pushes against the air at the rear and propels the balloon rocket forward."
2. It is said that when Robert Goddard, one of the modern day fathers of space travel, proposed that rockets could be sent to the moon, he met strong opposition. Many told him that this would be impossible since everyone knows that there is no air in outer space and the rocket could not work unless it had air to push against.
3. Since rockets do work in outer space, the exhaust gases apparently don't push against air to propel them forward. How do we explain their motion?

B. Demonstration

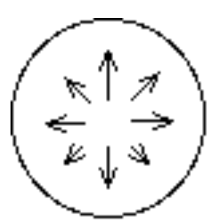
1. Obtain a cardboard box and remove the top. Cut out a flap (X) according to the picture below.

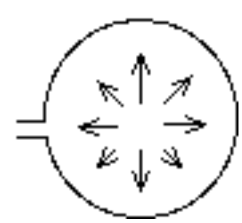


2. Begin the demonstration with the flap bent upward with the box resting on the table or floor.
3. Take a meter stick and move it repeatedly from A to B to A and also from C to D to C in rapid motion. This is to simulate the molecular motion inside the balloon where gas molecules hit all sides with about equal frequency.
4. Because balanced collisions (and thus balanced forces) are operating on each wall of the box in the four main directions equally, the box does not move very far, if at all, in any one direction. This would be analogous to the balloon that is sealed sitting motionless on the table.
5. Now open the flap X and repeat the hitting action. This time the forces at A and B still balance each other but the "molecules" striking the D wall are now unbalanced by no collisions at C. Consequently, the box moves forward (in the direction of D). This is analogous to the balloon with its nozzle open that results in forward motion.

C. Conclusion

1. It appears that the forward motion of the box is due to the "molecules" inside the box pushing on the box resulting in the forward motion, not the "molecules" pushing backward on the air outside the box.
2. Many students are going to have difficulty with accepting this idea. The forward propulsion of the balloon is due to the molecules inside the balloon pushing on the wall of the balloon not due to them rushing out the rear of the balloon and pushing on the outside molecules of air.





NO MOTION OF BALLOON **BALLOON MOVES TO**
RIGHT

3. In the case of the straw rocket, the air from the bottle launcher coming out of the glass tubing pushes forward on the blob of clay sending the

rocket forward.

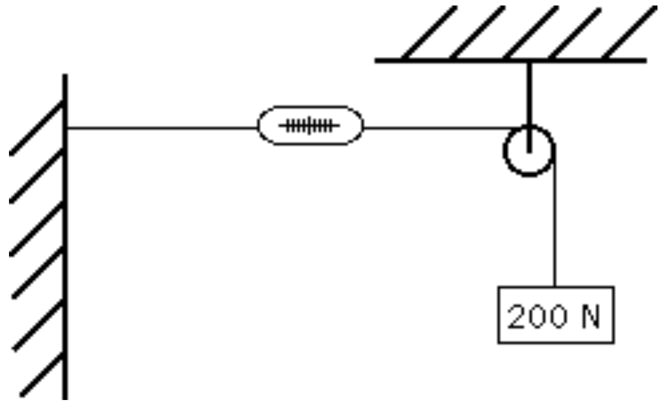
4. In both types of rockets the air inside the system pushing on the rocket sends it forward. But at the same time the rocket (balloon or wad of clay) is pushing back on the air!! This is what accounts for the air coming out the back.
5. In a general way we sum this up by saying that whenever one object exerts a force on another one, the second one exerts an equal and opposite force on the first one. Note that the two forces are not on the same object, however. This is generally known as **Newton's Third Law of Motion**.

D. Further examples

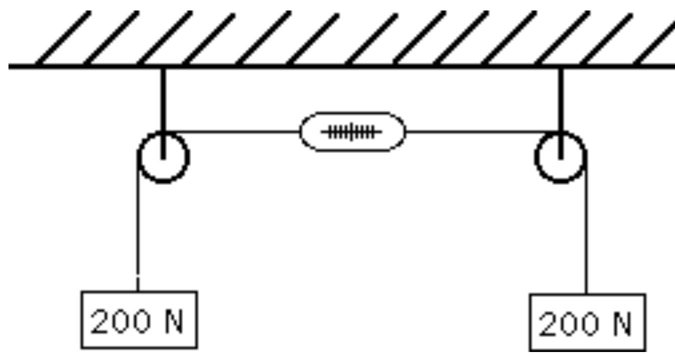
1. If you push against a wall, the wall pushes back on you with an equal force. It this wasn't true and you pushed harder on the wall, the wall would move. If, on the other hand, the wall pushed back harder on you, you would fall over backwards!
2. When you go swimming, you push the water backward with your arms, and the water pushes you forward with an equal force.
3. When you walk across the ground, you push against the ground and the ground pushes against you.
4. When the tires of a car push against the road, the road pushes back on the tires.
5. When the gases that come from combustion of the fuel in a rocket push forward on the rocket the rocket pushes backward on the gases which move backward out of the rocket.
6. What happens when you fire a rifle? The rifle acts on the bullet and the bullet acts on the rifle. The bullet goes forward and the rifle kicks backward.
7. In talking about Newton's Third Law it is often stated that for every action there is a reaction. What is often omitted is that the action force is on one object and the reaction force is on a different object. A simple method of determining these forces is to reverse the subject and the direct object of the sentences describing the forces.
   a.) The <u>boy</u> pushed the <u>wall</u>. The <u>wall</u> pushed the <u>boy</u>.
   b.) The <u>ground</u> pushed <u>me</u>. <u>Me</u> pushed the <u>ground</u>
   c.) The <u>rocket</u> pushed the <u>fuel</u>. The <u>fuel</u> pushed the <u>rocket</u>.

E. Tug-of-War

1. Lets assume that a boy is pulling by way of a rope on a wall with a force of 200 Newtons. This is almost enough force to break the rope but not quite.
2. Another boy equally as strong as the first boy removes the rope from the wall and now both boys pull in opposite directions on the rope. Will the rope break? [The rope will not break, however this is hard to convince many students of. Boy 1 is pulling on boy 2 while boy 2 is pushing on boy 1. The rope serves only to transfer the force.]
3. Lets use a spring balance, a pulley, a weight and some fishing line to illustrate this. See diagram below.



4. Have students predict what the reading on the spring balance will be. Most students will correctly predict 200.
5. Set up the situation depicted below and have students predict what the reading on the spring balance will be this time. If there are no guesses, give them three choices: 0, 200, or 400. If some still contend that it should be 400, ask them if the spring balance would read any differently if the left-hand pulley and weight were removed and the string was attached to the wall.

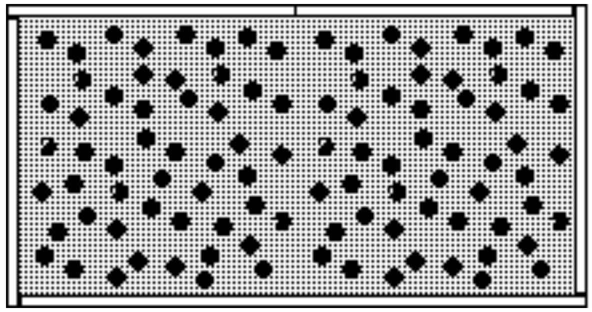


6. Remember these are examples of Newton's Third Law. In the first diagram the weight is pulling on the spring balance with a force of 200 while the spring balance is pulling on the weight with a force of 200. The force of 200 is transmitted through the spring balance to the wall. In other words the force of 200 of the weight is really pulling on the wall while in reality it is the wall pulling with a force of 200 on the weight. In the second diagram, the wall has just been replace by another weight pulling with a force of 200. This is no different than the wall pulling with a force of 200 as in the first diagram.

CONCEPT EXTENSION

A. The Rubber Band Roller-skate

1. Cut a rubber band and attach the two ends to the front sides of a roller-skate. (In place of a skate you could use a piece a wooden board resting on a large number of marbles. Use thumbtacks to attach the rubber band to the front of the board. Six meter sticks can be taped to the table to confine the marbles to provide a relatively friction-free surface upon which the board can ride. Obviously, if you have an air table, use it!!)



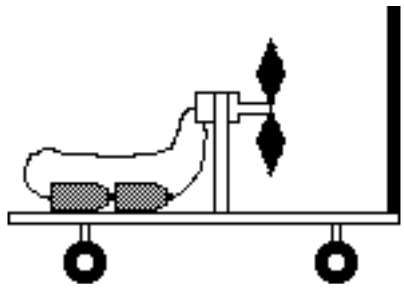
2. Tie a string to the center of the rubber band. Pull it back, (this obviously stretches the rubber band), and attach the string to the back of the skate. If using the board/marbles setup, attach the string to back of the board with another thumbtack.
3. Place a lump of clay at the center of the V made by pulling back the rubber band.
4. Predict what will happen when either the string is cut or a candle is put to the string to burn through it. What will happen to the clay? What will happen to the skate or board? If either, or both, moves, in which direction(s) will the motion be? How does Newton's Third Law explain what happens?
5. [The skate or board should go in one direction and the clay go in the other direction. the clay will shoot off fast while the motion of the skate or board will be much slower. The potential energy built up in the skate by stretching the rubber band pushes on the clay while at the same time (if we really believe in Newton's Third Law) the clay will push back with equal force on the skate. The reason the skate doesn't go as fast as the clay even though forces of equal magnitude are applied to the clay and the skate has to do with the larger mass of the skate. If the clay would weigh as much as the skate, then the clay and the skate would have equal speeds.]

B. Questions That Make You Go Hummmm

1. Why can you exert greater force on the pedals of a bicycle if you pull up on the handlebars? [When you pull up on the handlebars, the handlebars push down on you, and this force is transmitted to the pedals.]
2. Lets say you are weighing yourself on a set of bathroom scales. You are standing next to the sink in the bathroom. If at the same time while you are standing on the scales you reach under the sink and pull up on the sink, will the scales register your weight to be more or less than what they would register if you didn't pull up on the sink?
3. Lets repeat the question in the situation above except that you push down on the top of the sink instead of pulling up on the bottom of the sink. What will your weight be this time compared to what it would be if you did not push down on the sink?
4. [In #2 the scales would register heavy. Since you are lifting up on the sink, the sink is pushing down on you with an equal but opposite force and this would be transmitted to the scales. In #3 the scales would register lighter. Since you are pushing down on the sink it is pushing up on you with an equal force which tends to lift you up off the scales some and therefore they register light.]

C. Will It or Won't It Work

1. Obtain some type of device with wheels. Some options would be a roller-skate, a toy car, a dynamics cart, etc.
2. You also need some type of portable fan, possibly like one of those battery operated ones that you can attach to your visor in your automobile. If you wanted to do this on a large scale you could use a movable chair with wheels and a large electric fan with a long extension cord.
3. Affix to the rear of the cart a piece of cardboard (10 cm x 10 cm) that is perpendicular to the bottom of the cart.
4. Aim the fan at the sail (the cardboard).



5. Have students predict what will happen when the fan is turned on.
6. Have them predict what will happen if the sail is removed and the fan turned on.
7. Have the students explain what happens. This may prove more difficult for them to explain even though their predictions will probably be correct.