

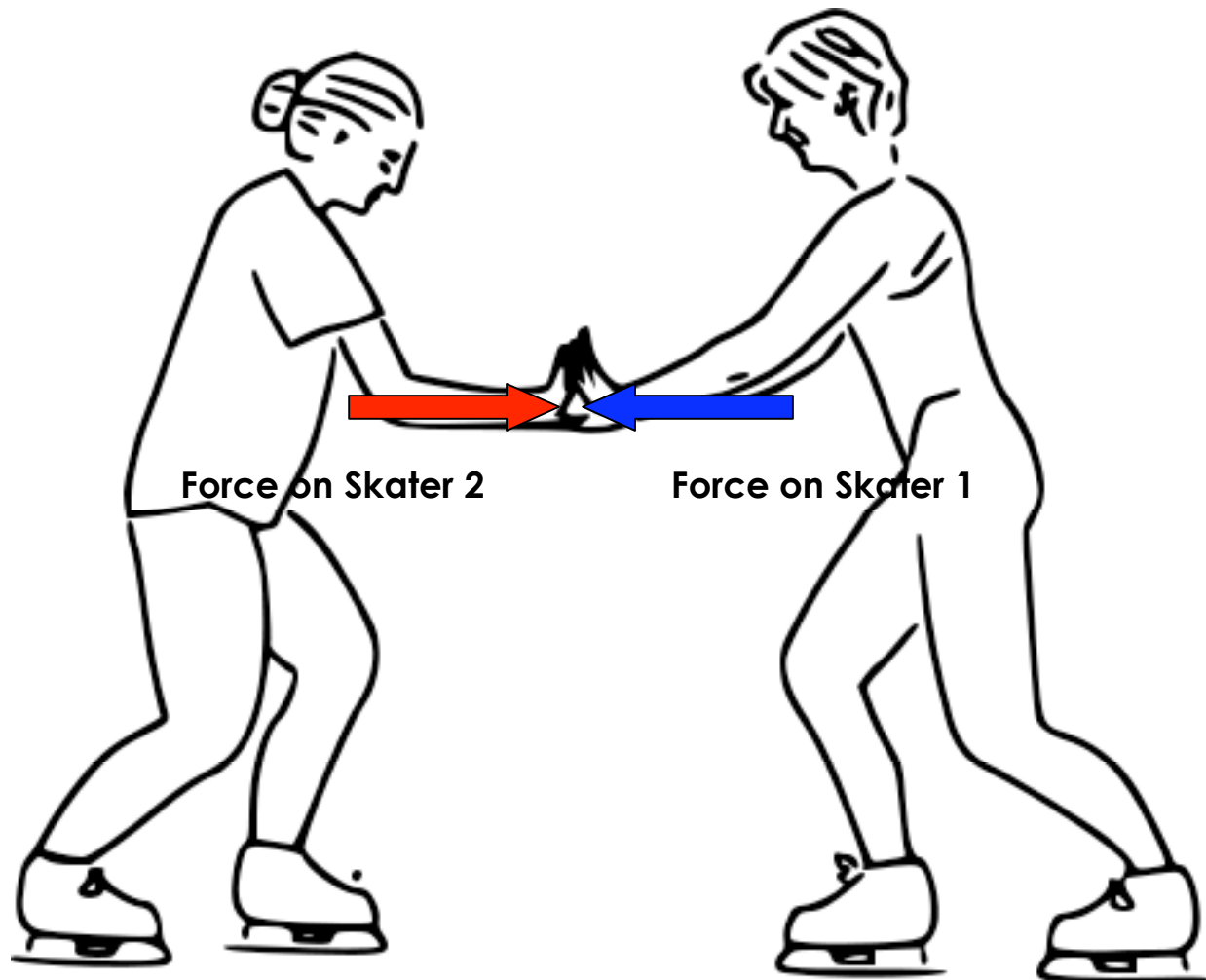
Newton proposed that whenever one object exerts a force on a second object, the second object exerts a force back on the first. The force exerted by the second object is equal in strength and opposite in force to the first force. If we think of one force as the action and the other force as the reaction, then **Newton's third law states that for every action, there is an equal and opposite reaction.**

Can anyone think of an example of an action-reaction pair? [jumping, rowing...]

In those examples, there was always a motion as a result of the forces acting against each other, right? But, can we always detect a motion when paired forces are in action? The answer is no. For example, if I drop my pen, we see gravity pull the pen towards the ground. At the same time, we know from Newton's third law, that the pen must be pulling Earth upward with an equal and opposite reaction force. But we don't feel a giant jolt of Earth moving in that direction because Earth's inertia is so great that its acceleration is too small to notice.

You may be asking yourselves whether or not action-reaction forces simply cancel each other out. Before, we talked about the fact that if two equal forces act in opposite directions on an object, the forces are balanced and no motion results. So, why don't the action-reaction forces cancel out as well?

The action-reaction forces don't cancel because they're acting on different objects. For instance, in the ice skater image, Figure Skater 1 exerts a right-ward force onto Figure Skater 2 and Figure Skater 2 exerts a left-ward force onto Figure Skater 1. The action-reaction forces act on different objects, namely the two different skaters.



Original Image by Benjamin Crowell. Source:
http://en.wikipedia.org/wiki/File:Skaters_showing_newtons_third_law.svg
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So, what does Newton's Third Law have to do with Astronomy and space exploration? Well, actually, a lot. Remember when we talked about our first solid proof of Earth being a sphere coming from our images taken on the Apollo 17 mission? Those images, the satellites we send into space, the telescopes that we send into space, the unmanned space missions to outer planets, and our manned exploration of the Moon all relied heavily on our knowledge of action-reaction forces.

Modern rockets were first developed in the early 1900's. They owe much of their development to a few scientists. In the early 1900s, the Russian physicist Tsiolkovsky described how rockets work and proposed designs for their construction. Robert Goddard, an American Physicist, also designed rockets, and in 1915 Goddard began to build rockets and test his designs.

Rocket engines are reaction engines. The basic principle driving a rocket engine is Newton's 3rd Law, which is what? ("for every action there is an equal and opposite reaction.") A rocket engine pushes its mass in one direction and moves via the reaction that occurs in the other direction.

[Demonstration: When you blow up a balloon and let it go so that it flies all over the room before running out of air, you have created a rocket engine. In this case, what is being thrown is the air molecules inside the balloon. When you throw them out the nozzle of a balloon, the rest of the balloon reacts in the opposite direction.]

Rockets are controlled by two of Newton's laws: $F = ma$ and "for every action, there is an equal and opposite reaction"

The Second Law

The mass of an object is what again? So, when considering a space shuttle or rocket, we need to consider the mass of the rocket. If you have ever seen the Space Shuttle launch, you know that there are three parts:

- * The Orbiter
- * The big external tank
- * The two solid rocket boosters (SRBs)

The whole vehicle—shuttle, external tank, solid rocket booster casings and all the fuel—has a total weight of 4.4 million pounds at launch – that's equivalent to about 45 humpback whales! 4.4 million pounds to get 165,000 pounds in orbit is a pretty big difference! The fuel weighs almost 20 times more than the Orbiter.

Just how fast does the rocket need to go? In order to lift off the ground, a rocket must have more upward thrust than downward force of gravity. Once a rocket is off the ground, it must reach a certain velocity to go into orbit. This velocity is known as orbital velocity. If the rocket has an even greater velocity, it flies off into outer space. Escape velocity is the velocity a rocket must reach to fly beyond a planet's gravitational pull. The escape velocity a rocket needs to leave Earth is about 40,200 kilometers per hour.

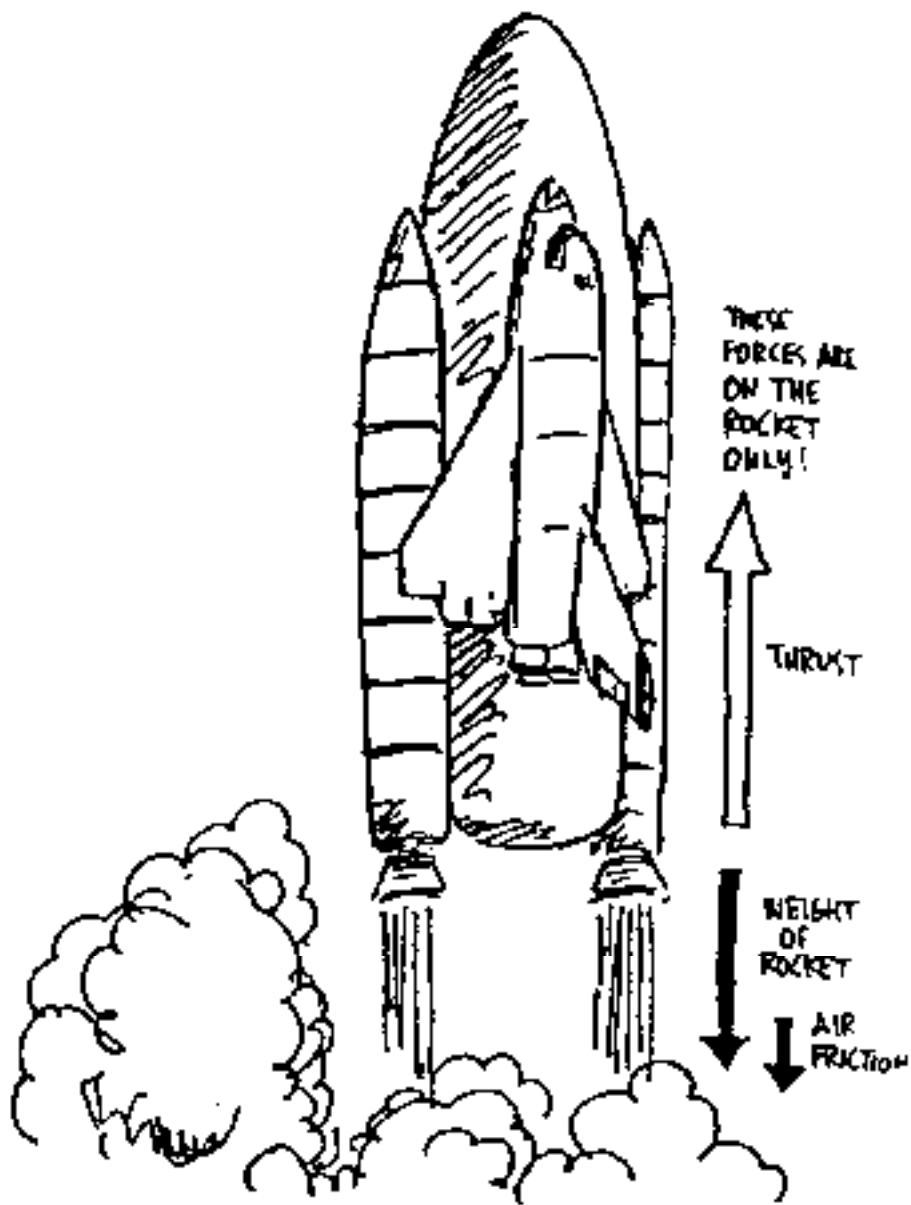
We need enough force to get something that's 4.4 million pounds to travel at 40,200 kilometers per hour! How can we do that considering the laws? As fuel burns during a rocket's ascent into space, what happens to the mass? [It is reduced] And, with increased distance from Earth, what happens to the pull of gravity? [It's not as great] So, the mass decreases, and the pull of gravity decreases. But how do we increase the acceleration?

The Third Law

The force that lifts the launcher comes from burning the fuel and converting it to energy. The gases produced by the conversion of gas to fuel escape through the nozzle at the base of the rocket. The gases exert an upward force that is equal and opposite to the force of the escaping exhaust.

So, by the reactive force of the gases combusting and escaping from the rocket, we increase the acceleration and decrease the mass of the rocket and the pull of gravity as we continue to move up that we are able to continue to accelerate into space even with the burning/use of fuel as we go.

** I need to make a version of this image **



Source:
<http://lasp.colorado.edu/~bagenal/1010/SESSIONS/7.UniversalMotions.html>