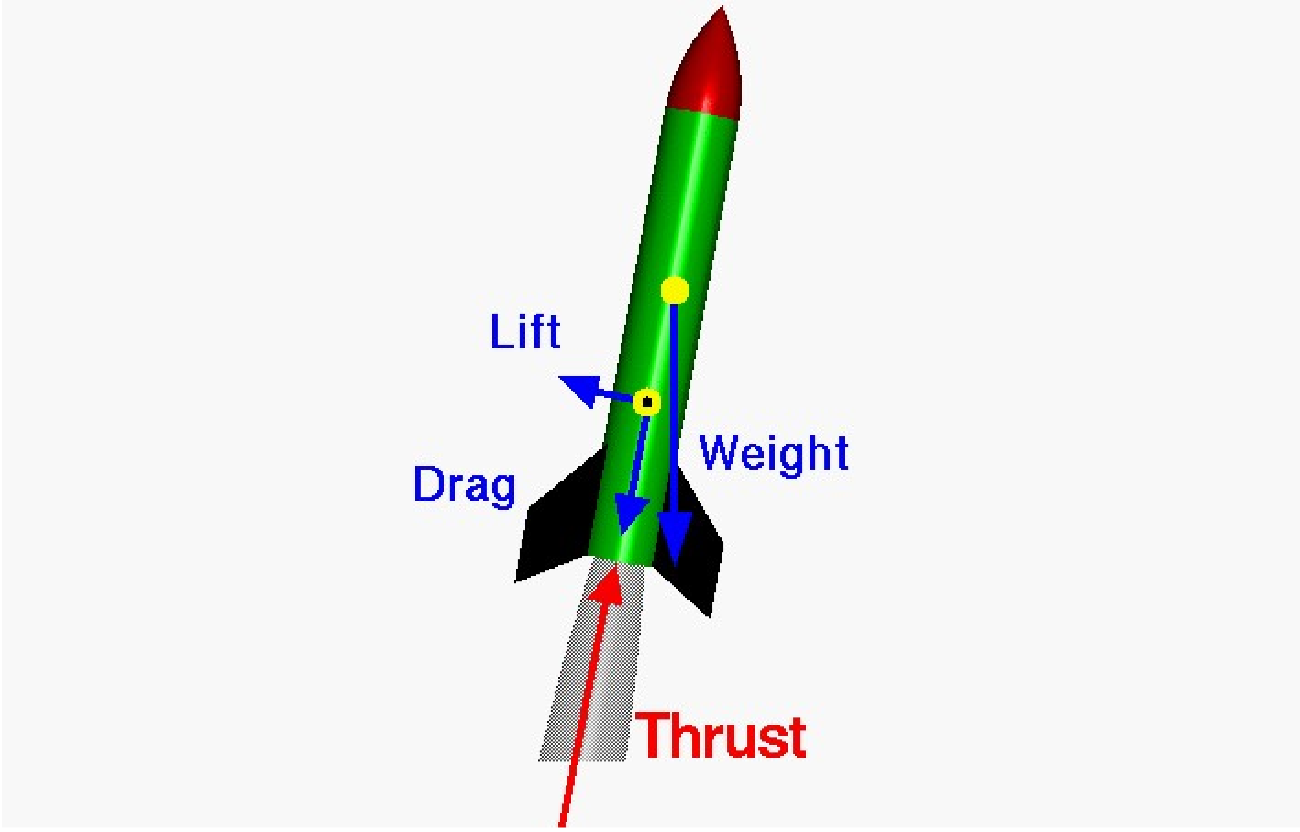
Rocket Thrust



Thrust is the force which moves the rocket through the air, and through space. Thrust is generated by the **propulsion system** of the rocket through the application of Newton's third law of motion; *For every action there is an equal and opposite re-action.* In the propulsion system, an engine does work on a gas or liquid, called a **working fluid**, and accelerates the working fluid through the propulsion system. The re-action to the acceleration of the working fluid produces the thrust force on the engine. The working fluid is expelled from the engine in one direction and the thrust force is applied to the engine in the opposite direction.

Forces are vector quantities having both a magnitude and a direction. When describing the action of forces, one must account for both the magnitude and the direction. The **direction** of the thrust is normally along the longitudinal axis of the rocket through the rocket center of gravity. But on some rockets, the exhaust nozzle and the thrust direction can be rotated, or gimbaled. The rocket can then be maneuvered by using the torque about the center of gravity. The **magnitude** of the thrust can be determined by the general thrust equation. The magnitude of the thrust depends on the mass flow rate of the working fluid through the engine and the exit velocity and pressure of the working fluid. The efficiency of the propulsion system is characterized by the specific impulse; the ratio of the amount of thrust produced to the weight flow of the propellants.

All rocket engines produce thrust by accelerating a working fluid. But there are many different ways to produce the acceleration, and many different available working fluids. Let's look at some of the various types of rocket engines and how they produce thrust.

The simplest rocket engine uses air as the working fluid, and pressure produced by a pump to accelerate the air. This is the type of "engine" used in a toy balloon or a stomp rocket. Because the weight flow of air is so small, this type of rocket engine does not produce much thrust. A bottle rocket uses water as the working fluid and pressurized air to accelerate the working fluid. Because water is much heavier than air, bottle rockets generate more thrust than stomp rockets.

Model rockets, and most full scale rockets use **chemical rocket engines**. Chemical rocket engines use the combustion of propellants to produce exhaust gases as the working fluid. The high pressures and temperatures of combustion are used to accelerate the exhaust gases through a rocket nozzle to produce thrust. There are two important parts of a chemical rocket engine; the nozzle, and the propellants. The nozzle design determines the mass flow rate, exhaust velocity, and exit pressure for a given initial pressure and temperature. The initial pressure and temperature are determined by the chemical properties of the propellants. Propellants are composed of a **fuel** to be burned and an **oxidizer**, or source of oxygen, for combustion. Under normal temperature conditions, propellants do not burn, but require some source of heat, or **igniter**, to initiate combustion. Chemical rocket engines do not typically rely on the surrounding atmosphere as a source of oxygen. Therefore, chemical rocket engines can be used in space, where there is no atmosphere present.

There are two main types of chemical rocket engines; liquid rockets and solid rockets. In a liquid rocket, the **fuel** and the **oxidizer** are stored separately and pumped into the combustion chamber of the nozzle where the burning occurs. In a solid rocket, the fuel and oxidizer are mixed together into a solid **propellant** which is packed into a cylinder. The propellant only burns on the surface. So, as the propellant burns, a "flame front" is produced which moves into the propellant. Once the burning starts, it will proceed until all the propellant is consumed. With a liquid rocket, you can stop the thrust by turning off the flow of fuel or oxidizer; but with a solid rocket, you must destroy the casing to stop the engine. Liquid rockets tend to be heavier and more complex because of the pumps used to move the fuel and oxidizer, and you usually load the fuel and oxidizer into the rocket just before launch. A solid rocket is much easier to handle and can sit for years before firing.

A new type of rocket engine is the **electric engine**, also called an **ion engine**. The working fluid for an electric engine is composed of very many, but very small, charged particles called ions. The acceleration of the working fluid is produced by electrostatic forces, not by combustion. Ion engines produce very small amounts of thrust, but can produce the thrust for long periods of time because the mass flow rates are very small. Ion engines have very high specific impulse when compared to chemical rockets.

Another new type of rocket engine is the **nuclear thermal engine**. In the nuclear thermal engine, a nuclear reactor provides a continuous source of heat which is used to accelerate the working fluid. The working fluid can be any gas which is heated as it is passed over or through the reactor and exited through the nozzle. The temperature of the exhaust, and the resulting exit velocity, can be much higher than for the typical chemical rocket. The only propellant is the single working fluid, so nuclear rockets are predicted to have very high specific impulse. Nuclear thermal engines are being developed under Project Prometheus.

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